IMPERIAL BUREAU OF FRUIT PRODUCTION

TECHNICAL COMMUNICATION No. 9

A REVIEW OF THE LITERATURE ON STOCK-SCION INCOMPATIBILITY IN FRUIT TREES, WITH PARTICULAR REFERENCE TO POME AND STONE FRUITS

By

G. K. ARGLES, Dip. Hort. (Wye), A.I.C.T.A.

November, 1937

Price 5/-

Published by the Imperial Bureau of Fruit Production, East Malling, Kent, England

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FOREWORD

By Professor V. H. Blackman, Sc.D., F.R.S., Director of the Research Institute of Plant Physiology, Imperial College of Science and Technology, London

Compatibility and incompatibility between stock and scion are matters of great practical importance to the fruit grower. They are in addition of high scientific interest to the plant physiologist. The harmonious growth of the grafted tissues of different species—and even of different genera—is a biological " miracle " to the peculiarity of which we are blinded only by familiarity. Such harmony is all the more unexpected since in an animal body we cannot graft together the tissues of different species ; there is complete incompatibility. Plants, however, can be grafted, and the study of such grafts provides a unique opportunity of investigating two living systems which have been brought into artificial union and compulsory interdependence.

This review is written for growers and for horticulturists generally ; it is not concerned with such intricate matters as the means by which the stock controls the growth of the scion which it supports. Indeed, living things are of such baffling complexity that as yet little progress has been made in this direction, though the search is being actively pursued. But even in a review which is essentially practical the complexity of the plant intrudes itself, and especially its plasticity, the way in which it is moulded by external conditions. This is well shown in the difficulty of defining incompatibility (pp. 53-57). The success of a graft, like that of marriage, may depend not only on the inherent qualities of the two individuals but also on the conditions, favourable or unfavourable, to which they are exposed during their partnership.

The literature of incompatibility is bulky, is scattered over many journals, and is often confused. The fruit grower, the horticultural investigator and the plant physiologist are all in debt to the Bureau for its foresight in commissioning this review and to Mr. Argles for the skill with which he has carried through a heavy and difficult task.

INTRODUCTION

We no where Art do ſo triumphant ſee.
As when it Grafts or Buds the Tree ;
In other things we count it to excel,
If it a Docile Schollar can appear
To Nature, and but imitate her well ;
It over-rules, and is her Maſter here.
It imitates her Maker's Power Divine,
And changes her ſomtimes, and ſomtimes does refine :
It does, like Grace, the fallen Tree reſtore
To it's bleſt State of Paradiſe before ;
Who would not joy to ſee his conquering hand
O'r all the vegetable World command ?
And the wild Giants of the Wood receive
What Law he's pleas'd to give ?
He bids th'ill natur'd Crab produce
The gentle Apples Winey Juice ;
The golden Fruit that worthy is
Of *Galatea*'s purple Kiſs ;
He does the Savage Hawthorn teach
To bear the Medlar and the Pear,
He bids the ruſtick Plum to rear
A noble Trunk, and be a Peach,
Ev'n *Daphne*'s Coyneſs he does mock,
And weds the Cherry to her ſtock,
Though ſhe refus'd *Apollo*'s Suit ;
Ev'n ſhe, that chaſt and Virgin-Tree,
Now wonders at herſelf, to ſee
That ſhe's a Mother made, and bluſhes in her Fruit.

Abraham Cowley.*

The use of rootstocks to permit rapid multiplication of fruit tree types possessing desirable characteristics dates from very early times, and in all probability the first stocks were merely seedlings of the same species as the scion variety ; but it has also for long been realized that by utilizing stocks of different species the habits of growth and fruiting of scion varieties may be modified and altered in various advantageous ways. Thus for centuries the quince has been used in Europe as a dwarfing stock for pears to encourage precocious fruiting and to adapt the pear tree to garden culture, while for apples the vegetative propagation of dwarf clones such as Paradise has been developed for the same purpose. In comparatively recent times the expansion of fruit growing industries into many new regions of widely differing soil and climatic conditions and the requirements of modern markets have led to a large increase in the number of fruit varieties grown. Many old varieties have been eliminated and superseded by new ones, in order that the needs of each particular locality may be as adequately served as possible. Similarly, new rootstocks have been required not only for such purposes as dwarfing, but for the adaptation of these new varieties to factors such as winter cold, drought and soil alkali, and for resistance to certain diseases and pests. By contrast with the raising of new scion varieties,

* From a Poem entitled " The Garden " in " The Works of Mr. Abraham Cowley ", 1688.

however, the widespread practice of propagating stocks from seed has made selection within each species to a large extent impracticable, and to fulfil the desired requirements it has, therefore, often been necessary to introduce stocks of species different from that of the scion. So, for example, we find *Pyrus baccata* used as a winter hardy stock for apples, *P. Malus*, peach and myrobalan plum used as stocks for apricots on soils not suitable for apricot roots, and *Prunus Davidiana* introduced as an alkali-resistant stock for stone fruits.

The failure of certain plants to intergraft and grow satisfactorily is a well-known phenomenon and is attributed to what we term incompatibility or uncongeniality between stock and scion. So long as the great majority of the rootstocks used were seedlings of the same species as the scion varieties the number of failures so produced was probably comparatively small, but attendant upon the introduction of many new species as rootstocks a considerable increase of incompatible combinations has been reported. Moreover, the problem of incompatibility has recently assumed a position of much greater importance on account of the numerous investigations on the reciprocal influences of stock and scion, for until it is solved or its true status determined, no final assessment of these influences can be made. The present position in this respect, however, gives small reason for satisfaction. The causes of incompatibility have received comparatively little attention and remain obscure, while among horticulturists its existence has often been accepted without question to account for various disorders from which fruit trees may suffer but which may actually be due to other factors. The purpose of this review, therefore, is not so much to offer an explanation of the phenomenon as to assemble and present what information we already possess in the hope that it may prove helpful to future investigators of the problem. The paper is divided into three main sections. In the first of these the disorders or manifestations commonly associated with incompatibility are discussed with a view to indicating to what extent they may be relied upon as symptomatic of the phenomenon ; secondly, an outline is given of some theories advanced as to the fundamental cause or causes of incompatibility ; and thirdly, a section is devoted to the subject of stock-scion incompatibility as it applies to the major pome and stone fruits grown on various rootstocks. In this last section much of the information collected is presented in tabular form, both for the sake of brevity, and in the hope that this method will supply a simple and rapid means of reference to any particular combination.

I. DISCUSSION ON THE MANIFESTATIONS OR SYMPTOMS OF INCOMPATIBILITY

Gardner, Bradford and Hooker devote a chapter in their book, *The Fundamentals of Fruit Production* (52) to the reciprocal influences of stock and scion. In introducing the subject they write :—" Grafts between certain plants are successful ; in many other cases the results range from partial success to utter failure. Sometimes there is immediate failure to unite, sometimes the grafts unite but the death either of cion or stock –generally the cion—occurs in a short time ; again the grafted parts may unite but there will be an ultimate failure in stock or in cion. On the other hand, as with apricot on plum and on peach in New York, plants may live a considerable time and function fairly well, under favourable conditions, without a very successful union of stock and cion and it is only an untoward incident, such as a high wind, that reveals the defective union."

The terms " incompatibility ", " uncongeniality " and " lack of (graft-) affinity " have been used by various authorities to denote almost any symptoms which might suggest a discordant association between a species or variety used as a rootstock and another species or variety used as a scion. The types of failure mentioned by Gardner, Bradford and Hooker probably represent the manifestations of incompatibility most commonly reported in papers dealing with the propagation of fruit trees, but there are, in addition, several other symptoms which have been considered at one time or another to indicate a similar condition. The various unsatisfactory results which may be produced by the different graft combinations which lie within the scope of this review are, therefore, summarized for the sake of convenience under the following group headings :—

1. Combinations of species or varieties in which no union is formed when the component parts are budded or grafted together. These are sometimes referred to as showing complete incompatibility.
2. Combinations in which the percentage of unions formed is relatively low.
3. Combinations in which union occurs and in which the scion bud develops into a shoot a few inches long, but then dies back or breaks off at the point of union. Similarly combinations which grow apparently normally for a period in the orchard but tend to break off during windy periods or to decline and die before the initial vigour of the trees or of their component parts grown separately would appear to warrant. The first of these are sometimes regarded as showing complete incompatibility, and the second partial or delayed incompatibility.
4. Combinations which produce symptoms of ill-health.
5. Combinations which produce dwarfed or stunted trees.
6. Combinations in which the growth of the scion outstrips that of the stock or vice versa, and which tend to produce a swelling at, or just above or just below, the union.

It is at once evident from an examination of this list, that in several cases factors other than incompatibility may produce effects very similar to those noted. Thus, for example, complete failure may result from budding at the wrong time of year ; an unhealthy appearance or premature decline may be caused by a lack of essential nutrients ; and it is conceivable that dwarfing due to stock influence may sometimes be confused with stunting attributed to lack of affinity. It is perhaps only in the case of well-established trees which suddenly break at the point of union that no alternative explanation seems feasible. The evidence for and against the use of the term " incompatibility " to describe these various results is considered

in subsequent sections, but first, since the majority of failures appear to be associated with some disorder in the region of the graft union, it would seem desirable briefly to outline the normal internal processes involved in uniting compatible stock and scion tissues.

Formation of the normal graft union

The first step in the formation of a graft union is the production by both components of meristematic callus tissue, which, according to Bradford and Sitton (17) in a study of apple and pear grafts, resembles that formed in the healing of external wounds, but is developed under rather more favourable conditions. In the case of apples, Sass (157) found that this callus is produced exclusively from tissues lying outside the xylem cylinder, but adds that any of these tissues, excluding the periderm, may proliferate and the cambium itself may actually contribute very little. No proliferation occurs during the first season from the xylem ray tissues although these cells are living, and the presence of varying amounts of callus between the original stock and scion xylem elements is explained by the continued division of cells of the calluses formed outside this region, after union between them has been established. In other plants, however, different tissues, including the medullary rays, may be involved in the production of the callus cushions. Thus in cleft grafts of *Hibiscus Rosa-sinensis*, Sharples and Gunnery (160) discovered that the cambium plays no part in the early development of callus, but that both bark and wood callus were formed predominantly from ray elements. On the other hand Eames and MacDaniels (47) regard the ability of the cambia of both stock and scion to produce callus and unite to be the normal basis of successful budding and grafting, and Smith (167) referring to stem cuttings of clematis also notes that callus production begins in the interfascicular cambium, but adds that contributions are ultimately received from medullary ray cells, cortex phloem and any living cells in the pith. In other words callus production is initiated in cells which have remained meristematic, but is later assisted through a resumption of the embryonic state by mature tissues.

Unobstructed contact between the respective callus pads of stock and scion favours a mingling of the parenchymatous cells and the continued proliferation of a mixed callus. No method has yet been devised for distinguishing microscopically between stock and scion callus cells, which are normally similar in such trees as apples, but it was established many years ago by Hoopes (94) and Waugh (186) among others that no fusion occurs in the mixed callus to form a hybrid cell, and that the union of calluses must always be regarded as in the nature of a dovetailing of the individual cells. In *H. Rosa-sinensis*, Sharples and Gunnery estimated the contributions of callus by stock and scion to be approximately equal at all times. In apples, however, Sass discovered that the amounts of callus contributed by each member, as indicated in the early stages while the respective calluses were still distinguishable, were not necessarily equal, but that either stock or scion might be responsible for most of the callus formed. Shippy (164) on the other hand found that both scion and root cuttings of several apple varieties exhibit marked polarity as regards the amount of callus produced, and states that, although many observations indicate that the root calluses practically as well as the scion, the top end of the root calluses neither as well as the basal end of the scion nor as well as the basal end of the root itself. Kostoff (111) does not say whether cuttings of solanaceous plants exhibit similar polarity, but notes that in grafts it is the stock which provides most of the uniting tissue, apparently owing to an insufficient water supply in the scion during the first few days after grafting. When the union is complete, however, the growth capacity of the scion becomes greater than that of the stock, and in whip grafts food accumulation predominates in the lowest part of the scion resulting in asymmetrical development of the callus. During the processes of union the cells injured during the graft operation gradually disappear, due, it is thought, to certain lytic phenomena. Nests of bacteria were observed in the region of the callus pads, but these are also apparently eliminated as the union becomes established.

The establishment of cambial continuity is regarded by Sass as the next step. In well-matched grafts an arc of cambium, continuous with the respective stock and scion cambia, is differentiated from the cells of the intervening callus. Bradford and Sitton observed a

similar process, and point out that, as in the healing of external wounds, marked adaptability to conditions is shown, the explanation of which lies probably in the readiness with which cambium may be transformed into parenchyma and with which cambium may be formed from parenchyma. This effect is considered to be enhanced by the large amount of parenchyma formed and its comparative self-sufficiency, so that even grafts with poorly fitting edges may make good unions if the scions live long enough. It is interesting to note, however, that in contrast to these findings Kác (106), also studying the grafting of fruit plants, discovered that the differentiation of meristematic tissue begins at the periphery and proceeds inwards, while Crafts (34) found that in tobacco grafts the first stage in the establishment of normal continuity was the production of vascular strands differentiated from the callus and that the cambium arose as a second stage in the tissues lying within these strands. In this case the orientation of the cambium initials was shown to be dependent upon that of the original vascular strands ; where the stock and scion were well matched the strands were short and straight, and the cambium then resembled in form that of the normal stem ; where the matching was poor the strands were long and tended to be crooked, so that the cambium initials developed in varied patterns. Crafts considers that unions of this type may be so rough as to hinder conduction, but adds that where no incompatibility exists they usually become smoother with time.

The completed cambial layer sheathing the union subsequently lays down a vascular cylinder which comprises the second annual ring of the tree. Sass states that the relative size and vigour of the grafted tree by the end of its first growing season seem to depend very largely upon the continuity of this second annual ring. Changes that may occur in the first annual ring, that is in the stock and scion tissues formed before the graft was made, are thought probably to have no influence upon the development of a successful union. In the formation of new tissues following the establishment of cambial continuity, differentiation of the cells of the scion appears, according to Proebsting (136), to be influenced by the cells of the stock adjacent to the scion cambium. Thus the cambium cells of the scion form medullary ray tissue when in contact with the ray cells of the stock, and xylem tissue when in contact with xylem, etc. In good unions the continuity of tissue is shown by the way in which the xylem elements are dovetailed together to make a well-knit mechanically strong structure. The influence of the scion upon the orientation of new stock cells has also been reported by Harvey (71) in a study of water conduction in apple and pear grafts. By inserting dye solutions into the scion and applying suction to the base of the stock he found that the course of the dye could subsequently be traced in sections of the stem. His observations indicate without any doubt that the scion whether grafted or budded cannot utilize any of the xylem elements existing in the stock prior to the operation. In a study of a three-year-old tree, which had completed one season's growth since grafting, he found that the cambium had started its activity at about the same time throughout the whole tree, but that at the point of union all stock xylem elements formed during the previous season had been directed towards, and connected with, those of the scion. On passing down the stock stem into the tap root, however, the thickness of the xylem directed in this way towards the scion became less and less until near the base only a few scattered vessels formed at the extreme end of the season's growth were still connected with the scion. The amount of xylem of this annual ring not connected with the scion increased from zero at the union to include the entire width at the base. This, he considers, suggests that changes in the orientation of the cambium's activities had been initiated by the scion, and that this influence was gradually extended down to the roots, the cambium at any given point responding as soon as the influence reached it.

The formation of the union in shield budding is described by Bradford and Sitton (17). It differs from grafting in that primary union is established between callus parenchyma produced by the stock meristematic xylem tissues and the shield bud cambium. Some measure of grafting may, however, occur along the edges of the shield, and, if any considerable amount of wood is present in the bud as in chip-budding, this may be accentuated to an extent at which the union may best be regarded as a graft. In any case development after the union is formed is essentially the same in budding as in grafting with the sole difference that there is no central core of disconnected xylem tissue. Proebsting (136) describes the first growth direction of the bud on

breaking as resembling that which a lateral bud would take. Later, when the section of the stock above the bud is cut off, the scion grows over the cut surface, and the growth rings in a normal union thereafter tend to form continuous cylinders. It may be added that the extensive literature on the processes involved in the formation of graft and bud unions is reviewed in some detail by Mendel (126) in a recent paper on the anatomy and histology of the bud-union in citrus.

In so far as the problem of incompatibility is concerned no evidence has been encountered which suggests that the one method of propagation may produce effects essentially different from any other. It is true that in a rootstock experiment with plums at East Malling Hatton and others (80) found that the symptoms of incompatibility were generally manifested earlier in budded than in grafted material, but the ultimate result was failure of the trees in both cases. Moreover, no evidence has been seen that suggests that in a congenial combination the mere act of budding or grafting when properly performed has any adverse effect by itself upon the development of a tree. On the other hand, it is worth noting that Halma (68) considers that the method of propagation may influence the effect of the scion upon the stock. He describes changes in the inherent form of the stock root system and in the external colour of the roots which occurred when Eureka lemon scions were grafted on to twigs or root pieces of sour orange, but which were not apparent in budded trees of the same combination. Among apples Gossard (60) found that the more successful the union formed, the more was the stock root system influenced by the scion variety.

Factors governing the success or failure of grafts or buds to form a union with the stock

1. *Incompatibility*

There will probably be general agreement with the statement that however certain combinations of plants may be budded or grafted together no union will take place between the stock and scion. This is easily understood in the case of plants botanically quite unrelated and structurally quite different, but since such extreme differences do not come within the realm of practical fruit growing they need not be considered here. There are in fact relatively few combinations mentioned in horticultural literature that will not form a union of any sort, and it is rather with cases in which the percentage take of buds or grafts is comparatively low that the nurseryman is concerned.

In this connexion, however, there appear to be two distinct schools of thought as to the interpretation and use of the word " incompatibility ". Gossard (60) in the United States conceives the expression congeniality and its synonyms on a very wide basis " as the phenomena associated with the formation of graft unions and the subsequent fate of the grafts ". In investigations on apple grafts he, therefore, regards the percentage of successful unions made to be directly proportional to, and thus a true criterion of, the degree of congeniality existing between a rootstock and scion varieties. This conception is also apparently held by Roberts (152) who describes fuzzy-rooted potentially burr knotted apple seedlings and seedlings which have been injured by aphis at the point where the grafts were made as being more congenial than " normal " roots because they gave relatively more and better unions, whereas seedlings with " smooth " roots, unbranched and with a " hard " appearance, are considered to be less congenial because they gave a poorer stand of grafts than did " normal " roots.

On the other hand Hatton (73), and Amos and others (2) appear to regard incompatibility as a result of the reaction between any two individuals and one which may or may not be manifested in failure to form a union. They certainly do not regard the number of successful unions formed as in direct proportion to the degree of compatibility existing between stock and scion. Thus in some cases where they tabulate the percentage take of buds of a large number of combinations tested as a possible indication of compatibility or the reverse, they are careful to point out that no definite opinion can be based upon results obtained in one or two years, owing to the existence of factors other than incompatibility which may adversely influence the formation of unions in certain seasons. It is, in fact, the principal object of this section to

discuss these other factors with a view to indicating how much reliance can be placed upon a low percentage take of buds as a symptom of inherent lack of affinity between stock and scion. When this has been done, and the other manifestations of incompatibility have been discussed, it should be easier to examine the two conceptions of incompatibility, just outlined, upon their proper merits (see Conclusions, p. 53).

2. *Varietal peculiarities and the method of propagation*

It is at once evident from an examination of the literature that the percentage take of buds or grafts of any given variety on a particular stock, or the stand of maiden trees produced, are not necessarily a true indication of the success or failure of the combination throughout the lifetime of the trees. Hatton (80) and Amos and others (2) instance several cases of plum stocks, which when worked with certain varieties produce very good stands of one-year-old trees, although within the next year or two these all die—owing apparently to " delayed incompatibility ". The reverse is also found in combinations which rarely produce more than a moderate number of successful unions, but in which all the trees formed are subsequently successful. A comparison of the mahaleb and mazzard cherry stocks affords another good example. Several authorities (3, 7) refer to the fact that mazzard is less easy to bud than mahaleb, and forms an inferior nurseryman's tree, but in later years in the orchard there are indications (98, 138) that both sweet and sour cherry varieties on mahaleb may exhibit symptoms of delayed incompatibility, whereas on mazzard no evidence has been encountered which suggests that either are ever incompatible. It is well known, too, that varieties respond with different degrees of success to the several ways in which the component parts may be joined together ; hence, various systems of grafting and budding have had to be devised to give the most satisfactory results. In general, where there is any question of partial incompatibility, Hatton (76) has found that whilst it might be difficult or impossible to get a good permanent union by budding this may often be obtained by grafting ; similarly Gardner, Bradford and Hooker (52) note that the approach graft frequently succeeds when other methods fail, and Kostoff (112) obtained a higher percentage of successful unions among solanaceous grafts when the components were moistened with a 1% solution of magnesium sulphate in water. Finally, Roberts (152) reports that the factors governing the grafting quality of scions in apples seem to be as elusive as those of the stock ; scions taken in various ways from trees receiving differential treatments often gave different results, and these results varied from year to year and also according to variety.

These examples would appear to indicate that, whether or not the compatibility between stock and scion is complete, success in the formation of unions depends to a certain extent upon factors peculiar to the individual varieties concerned. In particular instances these factors have been established. Thus Hatton (80) writing of the plum rootstock, Brussels, states that to obtain the best results with any variety budded on to it the operation must be done early, because this stock is very apt to dry out ; and likewise with the plum variety Jefferson's Gage the failure of the buds to unite satisfactorily with various stocks has been associated with a peculiar development of the node which makes manipulation of the buds difficult. Similarly Bioletti and others (12) discussing the grafting of grape vines state that " the facility with which the mechanical operations of grafting can be accomplished depends on the size and straightness of the cuttings (stocks), the length of internodes, the size and abundance of buds and laterals, the size of the pith, the firmness of the wood, and the difficulty of disbudding ", and add that " these qualities vary with the variety and with the conditions of climate, soil, pruning, training, and cultivation under which the mother vines are grown ". The condition of the cuttings is also considered to be of great importance in connexion with the percentage of unions formed and their perfection. Cuttings either of stock or scion from vines weakened by disease or overbearing, or which are immature through lack of heat or premature autumn frosts, and cuttings which have been injured through storage in too wet a condition will give poor results. In apple grafts, Gossard (60) considers that the relative successes obtained in forming unions depend upon the state of activity of the stock cambium. He defines an " active " type of cambium as one in which the cambial region consists of numerous layers of thin-walled cells, although not necessarily

engaged in producing new tissues at the time of grafting, whereas an " inactive " type of cambium consists of a small number of layers of thicker-walled cells with the cells on either side of the cambial region appearing to be maturer than those in the " active " type. The production of bast fibres was inversely related to cambial activity, and so this too was correlated inversely with the percentage of successful unions formed. Thus when apple stocks were divided into four groups in order of cambial activity—piece roots from Kansas seedlings, from Doucin trees, from Wealthy trees, and from *Pyrus ioensis* (*Malus ioensis*) seedlings—he found that this order was in direct proportion to the success obtained in grafting, and in inverse order to the number of bast fibres present. Finally, he also found that the relative success obtained in rooting stem cuttings of apple seedlings ran parallel with the number of successful unions made when grafts were inserted on stocks of the same seedlings.

3. *Climatic conditions*

Shippy (164) studied the effect of temperature upon the formation of callus in grafts and cuttings of several varieties of apples. He found that the complete range permitting callusing in either case lay between 0° and 40° C. At 3° to 5° C. only a small amount of callus developed over a period of several months, and at the other end of the range, from 32° C. upwards, injury usually became apparent until at 40° C. the death of the tissues accompanied by fungus mould invasions always occurred within a few days. Between 5° and 32° C. the rate of callus formation, as indicated by the time taken to attain final volume, increased with the rise in temperature. For general purposes, however, he found that temperatures below, rather than above, 20° C. were conducive to the most satisfactory callusing. These general relationships were not altered by temperature fluctuations, and callusing was accelerated or retarded according to the degree and duration of the temperature.

The influence of atmospheric humidity on callus formation in apples was also studied by Shippy. He found that air moistures below saturation point resulted in desiccation of the tissues and had in general an inhibiting effect upon callusing. With cuttings, water present as a film enclosing the cut end of the shoot apparently provided the most favourable conditions for the uniform production of callus. In grafts, Sass (157) also stresses the adverse effects on cell proliferation of desiccation and the destruction of tissues by fungi as influenced by temperature and humidity, while practical confirmation of Shippy's conclusions regarding the effect of atmospheric humidity is provided by Chang (23). In grafting experiments with two pear varieties, Bartlett and Kieffer, on *Pyrus calleryana* he found that on dry days the percentage take of grafts tended to be low, whereas high relative humidity at the time of grafting, or adequate rainfall just before or just after the operation generally insured a good take. The varietal susceptibility of the Brussels plum stock to dry out, unless budding is done early, has already been noted in the previous section.

Shippy also found proper aeration to be an important factor in callus formation, although his data indicate that the amount of oxygen required need not be as high as the proportion of 20% found in air. Where oxygen is limited, however, the presence of high concentrations of carbon dioxide inhibits callusing.

Finally Baltet (9) considers the effect of climate upon the human element in grafting when he states that a calm atmosphere and warm rather than rainy or cold weather is both agreeable to the operator and conducive to the success of the operation.

4. *Size and age of stock*

There will be general agreement that stocks with girth measurements below and above certain limits will present difficulties in budding or grafting, but there seems to be little information available as to whether any appreciable differences in the stands produced may be expected within the limits of size and age commonly encountered in nurseries. It is true that Gleisberg (56) regards the age of the stock in top-working to be a factor adversely affecting the formation of a union and that Gossard (60) and Roberts (152) suggest that, in bench-grafting, roots from older apple trees may develop what they term incompatibility due to the cambium becoming less

active, but the only quantitative evidence on the effect of size appears to be that compiled by Tukey and Brase (177) from Montmorency cherry scions budded on to mahaleb stocks of different girths. They divided the stocks into three grades according to caliper measurement just above the crown ; $\frac{1}{4}$ in. and upwards, $\frac{3}{16}$ to $\frac{1}{4}$ in. and $\frac{1}{8}$ to $\frac{3}{16}$ in. The larger of these grades proved low in vigour, and gave a poor stand of trees. The two smaller grades were more vigorous, and both gave significantly better stands, despite the fact that in the smallest grade a number of plants were included which would normally be considered too small to bud. These results are of interest in showing how slight differences in size may have an effect upon the number of successful unions formed in cherries, but Tukey and Brase are careful to point out that the same size relationship does not hold good with other fruit trees such as apples and pears. It may be added that Smith (167) found that in stem cuttings of clematis the amount of callus formed varied with the age of the wood taken and with the amount of food reserves such as starch, a factor again partly dependent on age, as well as with the anatomical structure of different species.

5. *Position of the top bud of the graft*

In 1925 Roberts (150) examined 907 whip-grafted apple trees in Wisconsin to determine what effect the position of the top bud of the scion relative to the graft had had upon the take of grafts and subsequent growth of the trees. Four positions of the top bud were distinguished :

(i) the top bud of the scion was in line with the tongues on the matched side of the graft,
(ii) the top bud was above the lower lip of the scion,
(iii) the top bud was above the tongues on the mismatched side of the graft,
(iv) the top bud was above the upper lip of the stock.

The results obtained, which indicate the striking superiority of position (i) over the other three positions, are given in the following table :—

Position.	No. of trees.	% good.	% poor.	% with top bud dead.
(i)	343	91·9	2·3	0·3
(ii)	141	9·9	61·8	9·9
(iii)	182	0·0	88·9	7·8
(iv)	241	4·6	63·8	21·2

In the following year the same author (151) carried out a trial to test these results experimentally with specially prepared material. The scion variety used was Wealthy, the stocks large French seedlings, and equal numbers of the grafts were inserted in each of the four positions indicated above. The first position again gave a stand of trees markedly superior to the other three and also to a check treatment in which the scions were prepared haphazard according to commercial practice.

Swarbrick (172) conducted similar trials at Long Ashton using the apple varieties White Alphington and Bramley's Seedling on miscellaneous seedling stocks. Comparing the first and third treatments tried by Roberts, he also found that both varieties as maiden trees made significantly more growth when grafted in the first manner, but in take of grafts only the variety Bramley's Seedling showed a significantly higher percentage (9%) in favour of this treatment.

Bennett (10), however, obtained contradictory results when he tested the four positions indicated by Roberts with piece root grafts of the apple variety Gravenstein and the pear variety Winter Nelis on seedling rootstocks. The grafts were made in February, and records were taken of the number of successful unions formed and the growth of the trees up to the end of July. Not only did he find no definite correlation between the position of the apical bud of the scion and the percentage stand and growth of the trees, but such differences as did occur did not favour position (i) (top bud of scion in line with the tongue on the matched side of the graft) which gave the best results in both Roberts' and Swarbrick's experiments. Thus, with the apple,

it was position (iii) (top bud above the mismatched side of the tongues) and, with the pear, position (iv) (top bud above the upper lip of the stock), which produced the best stand and subsequent growth. Bennett therefore concludes " that, contrary to the results obtained by Roberts, there is little to indicate that the position of the terminal bud relative to the graft union has any bearing on the resultant stand of the grafted trees or the amount of growth produced under the conditions of this experiment ".

6. *Faulty manipulation in grafting*

It is clear that if grafting or budding is done very carelessly the component parts may fail to unite, but in addition it seems likely that even if the operation is fairly carefully performed failure to produce a good fit may sometimes prejudice the success of the union. Bradford and Sitton (17) consider that some contact between the cambia of stock and scion at the top of the stub is essential to the proper healing of graft unions. In inlay grafts, too, lack of pressure between stock and scion may jeopardize ultimate healing. On the other hand, Sass (157) states that uneven or excessive pressure may also prohibit proliferation locally by crushing the surface cells. The same writer also quotes Herse (92) as describing how in poorly-matched grafts, instead of a straight bridging layer of cambium being formed, a recurved cambial extension is differentiated from the stock and scion respectively. Subsequently there are produced on the margin of each member of the graft irregular and disconnected rolls of vascular tissue which may constitute more or less permanent barriers to union. A somewhat similar condition is described by Melhus and others (125) from a study of callus overgrowths in apple grafts. They found that in a graft with an overhanging scion tip excess callus first forms as a knot from the severed cambium of the scion. This subsequently grows backwards and fills the space between the stock and scion, so that when a phellogen layer is soon differentiated it cuts off and causes the death of the outer layer of proliferating cells of the scion callus. Thus the slower growing stock callus finds no meristematic tissue with which to unite and lack of continuity in the union results. Careful handling is also considered by Gleisberg (57) to be necessary in top-grafting, for, if the space between stock and scion is wide, callusing may not be completed and cambial continuity not established before desiccation and the entry of disease organisms attended by excessive wound gum formation may prevent further healing.

PREMATURE DEATH OF THE TREES AND BREAKING AT THE UNION AS SYMPTOMS OF INCOMPATIBILITY

The graft union is obviously at first a point of mechanical weakness in the stem of the tree, regardless of whether the combination is wholly compatible or not, and the only evidence encountered suggests that it may remain so for a considerable number of years. Breaking tests made by Booth (16) on ten-year-old apricot and plum trees growing on roots of the same species showed that a distinctly greater pull was required to snap the stems either above or below the union than at the union itself. There is, however, nothing to show that compatible combinations will ever break in this manner under normal conditions of climate and treatment, although cases of uprooting through the agency of strong winds are well known. Similarly there is apparently no information as to the relative strengths of graft and bud unions in the first year or two, but it may be noted that in the case of the former, Suit (171) found no significant differences between the mechanical strengths of carefully made wedge or cleft grafts, single-tongue or whip grafts and double-tongue grafts in apples, as indicated by the force in pounds necessary to snap the trees at the unions. These tests were made when the trees were two years old, and this in itself would seem to indicate that up to this age at any rate the unions of apple trees also constituted a line of relative weakness. The way in which the grafting operation was performed did, however, have an effect upon the comparative strengths of the unions produced. The use of nurseryman's adhesive tape as compared with string for tying the grafts was found to increase the strength of the union by 3 lb. regardless of the type of graft, and likewise well-fitted grafts were calculated to be about twice as strong as poorly-fitted samples of the same size.

These results, together with the studies of Bradford and Sitton (17), Herse (92) and Sass (157) on manipulative defects in grafting, suggest that in the early years at any rate the strength of congenial unions may be expected to vary to some extent according to the efficiency with which the operation is performed. On the other hand Waugh (186) considers cases of weak unions produced by faulty manipulation in the original setting of the graft as being somewhat uncommon, and moreover it is not unreasonable to assume that, as Crafts (27) found in tobacco grafts, many rather poor unions will gradually be adjusted to a more normal state as new tissues are laid down, whereas there is no record of unions deteriorating provided the component parts are compatible. Thus, apart from local failures due to such factors as disease, soil and climate, which fall outside the scope of the review, the cases in which any extensive number of trees die back within the first few years or break off at the union at any time in their existence can be explained only by the factor of incompatibility in a delayed or partial form. Reference to the section of this paper devoted to stock-scion relationships in the various fruit tree species will show that such wholesale failure is the general rule in certain combinations.

A number of papers have been examined which show that in certain, if not all, cases the direct cause of these manifestations of incompatibility is to be found in some structural defect or defects developing at the union during or after the processes of fusion. As long ago as 1904, Waugh (186) observed that in imperfect unions the continuity of new growth was more or less interrupted by the deposition of a certain amount of loose scar tissue such as is produced in the healing of wounds. Proebsting (135) in 1926 noted that no further information had come to light in the intervening twenty-two years which added materially to the information contained in Waugh's paper. He confirms the latter's observations on the gross characters of the union, and on the frequency of the occurrence of weak unions in some combinations due to the laying down of parenchymatous tissue at the line of the union. In a second paper two years later (136) he deals with the matter more fully, and states that perhaps the most common type of structural defect is that involving the deposition of wood parenchyma by the cambium at the line of the union, which may interrupt the vascular connexion to a considerable extent. This may be seen in any plane, and varies from isolated masses of parenchyma with vessels making fairly good connexions around them, to a practically continuous sheet between stock and scion. The result is a mechanically weak structure, which may survive several seasons, but will ultimately break off as the weight of the top offers more resistance to wind.

Proebsting (135, 136) also noted that distortion of the vascular bundles is commonly encountered in the neighbourhood of the union. In mild cases, such as are frequently shown by almond on peach, this may not cause mechanical weakness or functional disturbances, and has no apparent influence on the life of the tree. He considers, however, that when the distortion is very severe, so that vascular continuity may appear to be definitely broken, it is difficult to believe that no functional disturbance takes place.

Bradford and Sitton (17) in 1929 carried the matter a step farther. They consider that uncongenial grafts such as are represented by pear on apple and some pears on quince stocks differ from congenial grafts principally in failure to maintain cambial activity. Breaks in the cambium occur, apparently at the end of the growing season. The tissues often reunite, but this becomes less common with advancing years. As stock and scion expand the cambium failure leaves a zone of parenchymatous tissue, which is sometimes suberized, between them, and both the transpiration channels and the phloem become generally discontinuous.

The production of suberized tissue has also been observed by Proebsting (135) in combinations such as apple grafted on to pear which are usually incompatible and belong to the class in which early death or breaking at the union occurs. In this instance instead of, or associated with, the layer of parenchyma usually found in weak unions bark tissue was found to have developed. In the centre this was of indeterminate origin, but on either side appeared to be characteristic of the bark of its species, and in some cases it was continued inwards almost to the point at which the cambia were connected, leaving just sufficient new conducting tissue to permit the passage of foodstuffs and water. The union thus formed a line of mechanical weakness, and doubt is expressed as to whether such trees could survive a second season. Bark was found

to be present at the unions of both budded and grafted trees of several species*, but there was a high degree of variability among grafts of a given sort as to the frequency of its appearance and its extent in a given union. The same author more recently (136) confirms the formation of bark tissue in these and several other graft combinations†, and expresses the opinion that the incompatibility shown in such cases just falls short of the extreme type, in which no union whatever is formed.

Yet another type of structural defect is described by Proebsting in the same paper (136) as occurring in certain *Prunus* combinations such as Japanese plum on almond. In this case the entire xylem tissue between the medullary rays at the union degenerates into a gummy mass. So long as this is confined to the section of xylem existing at the original union no restriction will occur, but if it spreads outside this area the movement of water may be materially checked. It is pointed out, however, that a very similar condition has been noted occasionally in limited areas of tissue not situated at the union, and it is, therefore, considered possible that the gumming may be due to some entirely separate stimulus, and that its occurrence at the union may be merely a matter of chance.

The studies by Proebsting and by Bradford and Sitton have shown that failures found in many combinations of both *Pyrus* and *Prunus* species may be attributed to defects developing at the union. Their evidence and the instances of premature death and breaking at the union given by numerous other authorities also suggest that whereas in some cases the trees may succumb rapidly while still in the nursery, in others the majority of them may grow and crop satisfactorily and attain maturity without any indication of the presence of a weakened union. Thus, whereas with pear on apple the lack of compatibility almost always becomes apparent within a year or two after budding, with apricot on peach and on myrobalan plum the defective union may only be revealed by a few full-grown trees snapping off cleanly at the point of union during windy weather. In fact it is of interest to record that Bailey (6) prefers in New York these two stocks to the apricot root itself, because the latter, though apparently wholly congenial, does not grow well in most of the soils of that State, and the trees on peach and myrobalan, apart from the tendency to break, are much more satisfactory. A somewhat similar instance of defects appearing at the union late in the life of the tree has been found by Schuster and Miller (159) in the Persian (English) walnut variety Franquette growing on black walnut rootstocks in Oregon. The disorder was first observed in a fifteen-year-old orchard. Reduced shoot growth and premature defoliation of the scion accompanied commonly by suckering from the stock was followed ultimately by the death of the trees three or more years later. An internal examination of the union showed that the trouble was due apparently to a girdling effect brought about by the failure of the newly formed scion xylem tissues to unite with the stock. A dark, discoloured layer of a corky nature, attaining in some cases $\frac{1}{4}$ in. in thickness, was found to have formed between the two kinds of wood, eventually involving the whole circumference of the tree. The authors state that the causes of the disorder are not definitely known, but that attempts to isolate any parasitic organism have failed and it is therefore regarded as of a non-parasitic nature. The evidence would appear to point strongly to incompatibility as the explanation.

The parting of the scion from the stock appears to be a common manifestation of incompatibility among widely different types of woody plants, for, in addition to the examples among deciduous fruit trees noted above, it is stated by Clark (29) that an identical action may be witnessed in roses, conifers and many deciduous and evergreen, ornamental trees and shrubs.

The decline and death of trees after some years in the orchard, but at an age which their initial vigour would not appear to warrant, can only be ascribed with certainty to incompatibility between stock and scion when the shortening of life is marked and its occurrence widespread. The short life of many cherries on mahaleb seedlings is widely reported, but possibly because there is no breaking at the union, only a few writers such as Quinn (138) and Amos and others (2) associate the failure of the trees with possible incompatibility, and no attempt seems to have been

* *Pyrus Malus* on *P. serotina* and on *P. communis* ; *P. communis* on *P. Malus* and (var. Bartlett) on *Cydonia vulgaris* (*C. oblonga*) ; and *C. vulgaris* on *P. serotina*. *Prunus domestica* on *Prunus Persica*.

† In genus *Prunus* : Beauty plum, *P. salicina* on almond, *P. Amygdalus* ; Italian Prune, *P. domestica* on sweet cherry, *P. Avium*.

made to examine the unions internally. Similarly the sudden decline, at any time from twelve to twenty years after planting of many lemon trees on sour orange stocks in California, is attributed by Newman (130) to lack of congeniality, but although this is considered to be manifested from the first by the tendency of the scion to overgrow the stock there is again no evidence to show the internal state of the union.

Ill-health in trees as a symptom of incompatibility

In reviewing the literature on the disease relations of grafted plants, Bond (15) states that " on numerous occasions, grafting and budding have given rise to abnormal conditions resembling in effect an increased susceptibility to disease, but actually due to one of the following causes :— incompatibility between stock and scion ; transmission of an unsuspected virus disease ; imperfect manipulation of the graft union ". Chester (24) for example describes a disease of lilac he terms " graft-blight " of which the symptoms are those of general nutritional deficiency, but of which the cause lies in the use of certain privet stocks, *Ligustrum* spp., with which lilac is partially incompatible. Husmann (101) notes that the congeniality existing between vine combinations has a distinct influence on the resistance of Vinifera scions to phylloxera.

Amos and others (2) have also described how, with the pear varieties Dr. Jules Guyot and Reine des Poires on the clonal pear selection A3, the foliage turns a vivid copper beech colour in the autumn at a time when trees on other stocks are still dark green, and how on two apple stock selections from Long Ashton the variety Lane's Prince Albert is comparatively unproductive, tends to show a bronzing and purpling of the leaves in early autumn, and has bark presenting an unhealthy, cracked appearance. These they regard as being probable symptoms of delayed incompatibility between stock and scion, and, although all the trees are still alive at ten years of age, it seems very unlikely that they will survive for many more years. On the other hand there are undoubtedly many incompatible combinations in which an unhealthy appearance is the precursor of an early death, but at the same time it must be pointed out that there are also many equally incompatible combinations in which no signs of ill-health are apparent before the trees die. Thus Hatton (78) observes that there are certain combinations of pear on quince which may appear entirely normal and healthy up to the time when death suddenly supervenes, while Howard and Heppner (97) describe how peaches budded on to Myrobalan and Marianna plums grow vigorously until late summer in their first season, when a large number of the trees die without any previous warning.

There are, of course, numerous other factors which may produce an unhealthy appearance in fruit trees, and even if these cannot be determined it is obvious that to regard all unhealthy trees as incompatible, or, for that matter, all apparently healthy trees as compatible would be very unsound. Husmann (101) in particular stresses the difference between congeniality and adaptability. Writing of grape stocks he says :—" If we have grafted vines of which both the stock and the scion varieties are known to be suited to the soil and climatic conditions and they do not thrive, we know congeniality is lacking " ; and again shortly afterwards :—" The adaptability of varieties to soil, climatic and other conditions can often be closely judged after comparatively short observation, but the congeniality must be determined by actual test ". Gardner, Bradford and Hooker add that the term congeniality refers to the degree of success of the union between stock and scion, while the term adaptability refers to the relation of the combined parts to environment, most often soil and climate. Before any considerable reliance can be placed upon ill-health as an indication of incompatibility it would seem desirable either to establish its existence on a large scale and under different soil and climatic conditions or to obtain corroborative evidence through the appearance of some other symptom or symptoms of incompatibility.

In conclusion, several contradictory opinions may be quoted to illustrate how complex this aspect of the problem is and how little it is properly understood. Lindemuth (117), for instance, states that when varieties which start growing late in the spring are grafted on to types which start growing early an unhealthy tree is often the result owing to an accumulation of foodstuffs in the stock which the scion is not ready to utilize. In such cases canker-like lesions

may form at the point of union. The reciprocal effect of an early variety late is not, however, so conducive to ill-health. Baltet (9) agrees that it is better to unite by grafting only such subjects as have some similarities in time of starting growth as well as in point of vigour and hardiness, but his view on the reciprocal effects is diametrically opposed to that held by Lindemuth, for he states that, if any differences should exist, it is preferable that it should be the scion which starts growth the later of the two. Bradford and Sitton (17), however, issue a warning that distinction should be observed between the period of vernation and the period of cambium activity, since " such observations as are pertinent fail to link uncongeniality with wide differences in vernation or of elongating growth ". Baltet also considers that the scion should be the more vigorous and hardier component where the stock used is weak, because if otherwise the trees produced will be worthless. Similarly Dawson (44) considers that it is detrimental to graft a weak scion on a vigorous stock, because the former cannot absorb all the sap produced by the latter and this gives rise to a weak unhealthy tree. He states, however, that the reverse position, a vigorous scion on a weak stock is satisfactory, and instances the examples of pear on quince and cherry on mahaleb. On the other hand Booth (16), although agreeing that it is desirable to choose stocks and scions of fairly equal vigour considers that it is the combination of a vigorous scion upon a weak stock which most commonly results in injury. He describes how some peaches budded on Marianna plum stocks grew fairly well for two years, although the scion outgrew the stock as was shown by a marked overgrowth, but how during hot dry weather in the following season the trees wilted during the daytime and finally died. This result appears to confirm a contention of Daniel's (37) that when the functional capacity is greater in the scion plant than in the stock plant the interference with sap conduction normally resulting from cicatrization becomes exaggerated when the two plants are grafted, and the graft either fails to unite, or makes poor growth corresponding to that in a poor, dry soil. However, the contention that differences in vigour of stock and scion necessarily result in tree failure is clearly not applicable in the case of apples which have been shown to combine satisfactorily at East Malling regardless of the vigour of either stock or scion, and it seems likely from data discussed subsequently that it may be discounted for the other deciduous fruit types. Other conditions associated with unequal vigour of stock and scion are considered in the next two sections.

Dwarfing or stunting of trees as a symptom of incompatibility

The production of parenchymatous tissue, which is sometimes suberized, at the unions of certain uncongenial combinations, such as pear on apple and some pears on quince, results in both the transpiration channels and the phloem becoming generally discontinuous. Bradford and Sitton (17) consider that it is discontinuity in the phloem which is largely associated with dwarfing, the effect being apparently reciprocal ; the stock is dwarfed and in turn dwarfs the scion. From this it would appear that dwarfing may be a symptom of incompatibility, closely linked with some of the other symptoms already described. Amos and others (2), however, appear to distinguish between healthy dwarfingness, with which is combined precocity and heavy cropping, and dwarfingness which is accompanied by failure to crop and other undesirable characteristics. The first of these they attribute to stock influence and cite Malling Paradise apple No. IX as an example of a dwarf stock, which gives rise to dwarf trees when budded, but which has never been known to show any of the well-known symptoms of incompatibility such as failure to form a union, lack of health, or early decline. The second or unhealthy type of dwarfingness, which generally seems to be more extreme than the performance of other varieties upon the same rootstock would appear to warrant, they attribute to lack of compatibility between stock and scion, and instance several cases among plum and pear combinations which behave in this way. A particularly good example, however, seems to be that of the apple variety Wealthy on Malling No. I. This clonal apple stock when budded normally produces a vigorous to semi-dwarf tree, according to the scion variety, and at East Malling there is no record of any variety proving uncongenial when grafted on it. When tested by Shaw (162) in Massachusetts it again proved semi-dwarfing in its effect on the variety McIntosh, but with

Wealthy tissue produced was so small and low in cropping as to be worthless. In recent correspondence (163) the author of these experiments writes that he regards this as a positive case of incompatibility.

Results recently obtained by Colby (30) support the opinion that the graft union contributes little or nothing to dwarfingness associated with stock influence. He found that the roots of very dwarfed apple trees on Malling No. IX were not starved for starch, fat or nitrogen compounds, but were well stocked with these reserves, and he, therefore, concludes that the graft union in these trees did not prevent the downward movement of carbohydrate or soluble nitrogen compounds to the roots. The upward movement of these reserve foods to the shoots in early summer seemed, however, to be restricted, but this he attributes, not to poor xylem connexions, but most probably to early cyclic suberization of the small roots of the No. IX stock, which limits the supply of water to the tops.

It seems clear, therefore, that a distinction should be drawn between dwarfing due to stock influence and dwarfing due to functional disturbances at the graft union associated with incompatibility. Whether or not it is always possible, however, to make this distinction is still uncertain, and Amos and his co-authors also point out that it has yet to be determined whether the so-called healthy dwarfingness may not in fact be yet another manifestation of lack of complete affinity between stock and scion. Nevertheless there are many combinations which can clearly be assigned to one class or the other, and, if only to emphasize the different effects produced, it would seem to be advisable that persons studying stock-scion relationships should make it clear to which form of dwarfingness they refer. In this connexion the word " stunting " is sometimes used to describe dwarfing due to incompatibility, and its exclusive use for this purpose would appear to provide the necessary distinction between this form of dwarfing and that due to the use of a dwarf stock.

Unequal growth of stock and scion and swellings or overgrowths at the union as symptoms of incompatibility

In summarizing information on the problem of compatibility between citrus species, Haas and Halma (66) write :—" In general the degree of so-called congeniality or compatibility implies a comparison of the relative rate of growth of scion and stock ; the more nearly equal the rate of growth of scion and stock, the greater the congeniality or compatibility." Similarly Webber (188, 189) maintains that, where the union in citrus grafts is smooth and even and the trunk tapers gradually from the roots upwards as in normal unbudded trees, the congeniality between stock and scion should be considered complete. He interprets such development as indicating " a uniform balance of physiological functions and growth rate between stock and scion and a harmony of genetic relationships that permits a thorough and normal fusion of tissues at the bud union ". On the other hand there are certain combinations, such as lemons propagated on sour orange stocks, in which the growth of the scion tends to outstrip that of the stock. This results in a more or less marked overgrowth above the union, and the size and prominence of this overgrowth has been recently correlated with a dwarfing of the top and apparently with the premature decline of the trees. Combinations are also described in which the stock invariably overgrows the scion, an effect which appears to be due to a reaction between the two components by which the scion in some way stimulates the stock to grow more rapidly than it would normally. The trees again respond by being dwarfed and relatively short-lived. Among solanaceous plants Kostoff (112) discovered that in almost all intergeneric grafts it was necessary for the satisfactory growth of the scion to maintain an approximate equality between the amounts of green mass (leaves and stems) of the scion and the stock. As soon as the scion predominated it either killed the roots or so injured them that growth ceased. In graft unions between species, however, this phenomenon was not observed very frequently. In the same way discrepancies in growth rates and the appearance of overgrowth above or below the union are characteristic of certain graft combinations among deciduous trees. Thus Lindemuth (117) states that syringa on ash grows with such vigour that in a few years the stock becomes exhausted and dies. Among fruit species some varieties are more prone than others to this condition

regardless of the rootstock employed. Reimer (142) in Oregon for example mentions the Doyenné du Comice pear as a variety which always tends to outgrow the stock when grafted above ground, and in some instances he suggests that the difference between stock and scion may become so great as to impede the rapid flow of sap and ultimately cause the union to become so weak as to prove unsatisfactory. On the other hand he also observes that some Comice trees top-worked on other French pear varieties are among the most productive old trees of this variety in the locality despite the fact that the scions have far outgrown the stock, and, moreover, that when this same variety is budded at or below ground level no disproportionate enlargement of the scion occurs. Similarly Alderman (1) writes that *Prunus americana*, the only important plum stock in Minnesota, makes an excellent tree with new hybrid varieties when budded low, but is a very poor stock for top-working owing to the tendency of the scions greatly to overgrow the stock. As neither authority makes any mention of possible scion rooting in this connexion, these results suggest that unequal growth rates of stock and scion may not necessarily be an inherent characteristic, and, moreover, Bradford and Sitton (17) contend that differences in vigour can hardly be regarded as the basic influence in incompatibility, since wide differences of this nature in grafts of apple on apple normally show no symptoms of any disorder.

Another form of union overgrowth which has received considerable attention owing to its superficial resemblance to proliferations caused by the crown gall organisms, *Pseudomonas tumefaciens*, is the callus overgrowth or callus knot occurring in certain apple grafts. The studies of Melhus and others (125), Riker (143), Riker and others (144, 145, 146), Sass (157) and Suit (171) have shown that about 95% of these overgrowths are in no way associated with crown gall, but that in general they may be proliferated wherever there is a localized obstruction to effective vascular union. Excess callus is commonly produced, for example, in tongue grafts with an overhanging scion tip, whereas in wedge grafts, with which good matching is more easily obtained, the proportion of trees free from callus knots is normally considerably higher, and in budding wound overgrowths are practically eliminated. In this connexion callus knots should not be confused with burr knots which are commonly produced on some Paradise and Doucin stocks however the trees may be worked. Experiments have also shown that the method of wrapping the graft may exert an influence upon the formation of callus overgrowths ; the use of nurseryman's adhesive tape, for instance, has been found to reduce the number formed by comparison with the use of string, regardless of the type of graft. Differences in varietal responses have also been observed by Shippy (164) who considers it to be a very significant fact that varieties producing abundant callus under normal conditions have been found to be particularly prone to the formation of union overgrowths. Therefore, although the formation of the overgrowths may be accentuated by failure to procure a perfect union, they seem to bear no relationship to any possible incompatibility that may exist between the stock and scion.

Certain graft combinations also produce swellings at the union which do not necessarily seem to be associated with a different growth rate of stock and scion nor with the formation of excess callus due to an imperfect fitting of the graft. Riker (143) notes that enlargements at the union, several inches above the soil line, were frequently present in apple trees in Europe, and that these were generally attributed to lack of congeniality. A similar opinion is apparently prevalent in many other parts of the world, for the literature on stock-scion relationships contains many allusions to swellings and bulges as symptoms of lack of congeniality. This view receives some support from Proebsting (136) who notes that there is evidence of interference with translocation across certain unions, and that the appearance of swellings above the union supports this contention. Kostoff (111) also found that in certain solanaceous interspecific and intergeneric graft combinations large quantities of starch accumulated just above the union. This condition he associates with antagonism between stock and scion and regards it as the specific cause of proliferations at the union. On the other hand Shippy (164) comparing cuttings with low and high starch contents discovered no difference in the amount of callus produced basally by each, and concludes that, while Kostoff's conception of the dependence of callus development upon the accumulation of elaborated foods is an interesting possibility, it has not as yet been satisfactorily demonstrated that this reaction does occur.

That a swelling at the union is not necessarily an indication of incompatibility is maintained by Bradford and Sitton (17, 18) and by Amos and others (2). The latter, describing combinations of plums, peaches, pears, cherries and apples found to be either compatible or incompatible at East Malling in England, state that the presence of a prominent bulge cannot be cited as evidence of incompatibility, since in most of the unmistakably uncongenial combinations examined the bulge is entirely absent, whereas in many apparently thoroughly congenial combinations swellings have frequently been present.* Kobel (109) considers that swellings on the scion portion of the union, though mainly due to obstruction of carbohydrates, are also caused in part by proliferation resulting from the meeting of the two tissues. Bradford and Sitton found that tilting the scion, so as to prevent contact at the rim, gave rise to tissue changes which retarded covering of the stub and produced considerable swelling at the union ; a condition which appears to be very similar in origin, if not identical, with that found in the studies of callus knots described above. Internally, however, they discovered no evidence of tissue breakdown such as characterizes uncongenial unions, and they therefore regard these unions as compatible.

Finally assembling their data from pear on apple and pear on quince combinations they sum up the evidence on this aspect of the problem under the heading " New definition needed " by stating :—" Horticultural and botanical literature dealing with grafts teems with statements and inferences predicated on the assumption that a swelling at the union retards conductive processes of one sort or another, that it is *per se* an obstacle and an accompaniment, if not the cause, of uncongeniality. In the material here described the most uncongenial union (pear on apple) produced no swelling whatever and the greatest swelling found is due to mechanical difficulties rather than physiological incompatibilities. The magnitude of these swellings corresponds to the growth made by the cion ; where conduction, as indicated by growth, is best, the swelling is greatest. The relationship between swelling at the union and congeniality is negative, rather than positive, in this series. New consideration of old opinions based on what now appears to be an unreliable index of congeniality may well alter many conceptions of the relationship between stock and cion."

* Although, for example, no cases of failure have been recorded with apples worked on Malling Nos. IV, V, VII, VIII and IX, most varieties form distinct swellings at the union when grafted or budded on to these stocks.—Ed.

II. POSSIBLE CAUSES OF INCOMPATIBILITY

In general it seems that three plausible theories exist as to the underlying factors responsible for lack of compatibility between stock and scion, and these are discussed briefly in the ensuing sections, but it may be said at once that in all cases the evidence is as yet largely inadequate and at times somewhat conflicting, so that to all intents and purposes the causes of incompatibility may still be regarded as undetermined.

Differences in growth characteristics between stock and scion

Associations between incompatibility and unequal vigour of stock and scion and differences in the time of starting growth have been discussed in several of the sections devoted to the manifestations of incompatibility, and it is intended here merely to summarize the opinions already outlined. Some authorities regard an equal growth rate, and others a similar growth cycle, as essential accompaniments to a congenial graft union. In certain cases this qualification appears to be based on the normal habits of ungrafted plants, and in others on the behaviour of the components after grafting. In either case, however, any general assertion of cause and effect would seem to be ill founded for the following reasons : In the first place there are many apparently congenial combinations which exhibit growth differences between stock and scion just as great as some whose failure is attributed to these differences ; secondly, there are striking examples of failures occurring in combinations of plants which exhibit no appreciable differences in growth rate or in time of starting growth ; and thirdly, as Bradford and Sitton (17) point out, there is no evidence directly associating the failure of cambial continuity observed in certain incompatible combinations with either of these differences. It would appear, therefore, that, although in some cases these growth differences between stock and scion may be contributory factors in tree failure, they cannot in the light of present information be regarded as the basic causes of incompatibility.

Physiological and biochemical differences between stock and scion

It is an acknowledged fact that considerable physiological and biochemical differences commonly occur between plants united by budding or grafting, and it is the purpose of this section to illustrate certain of these differences and to note opinions which associate some of them with incompatibility between stock and scion.

Daniel (36) studying the physiology of herbaceous grafts found that with plants of the same family the scion normally uses the reserve food materials of the stock as though they were its own root reserves, and Hofmann (93) also considers it reasonable to presume that elaborated materials produced in the scion should, when the stock is of a different species, be capable of some alteration to enable them to be translocated to and utilized by the rootstock. On the other hand certain materials cannot traverse the union in some graft combinations. Thus, according to Daniel, the inulin produced in the *Cichoraceae* is not absorbed by any scion except those from plants whose roots contain inulin ; and in grafts made by Hofmann, anthocyanin, a soluble glucoside pigment, did not cross the union from a dark reddish-purple Refugee bean, *Phaseolus lunatus*, to a clear bright green Navy bean, *Phaseolus vulgaris*, whichever species was the stock ; while Biffen (11) noted that the boundary line between stock and scion was clearly marked in grafts of red beet with sugar beet. Similarly Roach (148) found that molybdenum, which occurred in the apple rootstock Malling No. IX up to the union, was absent from all parts of the scion variety Lane's Prince Albert, and Guignard (65) discovered that when either a herbaceous or a woody plant containing a cyanogenetic glucoside was grafted to another not

possessing this substance no transfer of the glucoside took place from scion to stock or vice versa. However, in certain cases materials present in the stock or scion will pass to another plant in which they do not naturally occur. Thus Daniel (36), for example, notes that atropine will pass readily from *Atropa Belladonna* into potato.

There is also clear evidence that the rootstock or scion may alter the chemical proportions of the other component so that some constituents may be present in greater or in lesser amounts than would normally be found in the unbudded plants. In this connexion Daniel (36) considers that two extremes must be recognized in grafts :—one in which water absorbed by the stock passes only in small quantity into the scion and another in which water enters the scion in very great abundance. At first these phenomena are of a physical nature, but later physiological changes take place by which the cell contents are modified, as is shown by the large amounts of starch formed in certain grafts. Reciprocal grafts of cabbage and turnip provide interesting examples of these extremes ; in cabbage on turnip starch and sugar in the scion increases to an extent above that which is normal, while in turnip on cabbage starch and sugar were unable to traverse the union. Similarly Laurent (114, 115) analysed grape vines, cabbages and haricot bean plants growing on their own roots and on several stocks, and found that the different stocks produced marked alterations in the carbohydrate and mineral contents of the scions. The particular rootstock used has also been shown by Eaton and Blair (48) to influence directly the boron content of the leaves of fruit trees and herbaceous plants. In reciprocal grafts of lemon and Chinese box orange (*Severinia buxifolia*) and of sunflower and artichoke, they found that the concentrations of boron in the leaves of the scion were reduced if grown on species normally accumulating lower concentrations and increased if grown on species normally accumulating higher concentrations. On the other hand, in an experiment with walnuts, the variety Eureka accumulated considerably more boron in its leaves than did the Payne variety when both were grown in the same cultures on black walnut roots, which is taken to indicate that boron absorption is not wholly dependent upon the rootstock employed. Haas and Halma (66) found a similar reaction in the soluble magnesium content of the bark of certain citrus grafts. The magnesium content in the stock varied according to the normal value of this constituent in the scion, whether low or high. Thus with lemon (low) budded on to sweet orange or grapefruit (both high) the stock showed a much lower magnesium content than when either was left unbudded, whereas with sweet orange or grapefruit (both high) on sour orange (low) the stock showed a considerably higher value than is normal. Similarly Jensen and others (103) found that the starch content of lemon trees propagated on the sour orange was appreciably greater than in comparable scions on grapefruit, while du Sablon (154) discovered that the stem of a pear variety grafted on to quince possessed a higher carbohydrate content than the same variety grafted on to pear stock in all months of the year except one. This latter difference is explained by the smaller requirement of the quince roots for reserve food materials, an opinion which is supported by Kobel (109) who claims that weak growing stocks need relatively little carbohydrate for their growth, so that in the aerial parts of the tree carbohydrates are maintained on a proportionately richer scale. In addition weak growing stocks extract from any given soil less mineral substances than do vigorous stocks ; the supply of nitrogen in the scion branches, therefore, remains comparatively small and the carbohydrate : nitrogen ratio is relatively high. Kobel concludes with a reminder that trees on dwarfing stocks are comparatively short-lived.

The intermediate piece of stem in double-worked apple trees has also been shown to influence the nitrogen and mineral contents of the scion. Colby (30) found that when the variety Wealthy was used as an intermediate the leaves of the scion were higher in nitrogen, but lower in iron and manganese, than when Jonathan was the intermediate.

Daniel (38) has found that the tendency in grafted plants for substances in the stock or scion to be increased or decreased or to be altered may exist even in cases when plants are grafted on their own roots. Nevertheless, he considers that in grafts of different plants the extent of this tendency corresponds to the more or less marked antagonism between the stock and the scion, an antagonism which manifests itself in the more extreme cases by the components breaking apart at the union.

Kostoff (111) considers that the factor causing accumulations of scion products such as starch above the union in certain solanaceous grafts is in all probability the " chemical specificity " of the organism rather than any lack of mechanism by which the products could be transferred to the stock. He argues that the antagonism which has been frequently shown to exist between scion and stock generally varies with taxonomic remoteness and is accompanied by certain morphological phenomena such as agglutination of the plastids and necrosis of the stock in addition to the accumulation of starch above the callus. Moreover, since such reactions are observed more often in intergeneric than in interspecific graft unions he considers it logical to assume that they occur when the biochemical nature of the two plants is very different. In other words it seems likely that while some of the products of the scion are changed into acceptable forms for utilization by the stock, other products cannot be so changed and being unacceptable tend to accumulate above the union. The failure of certain graft combinations may, therefore, according to Kostoff, be explained by the " chemical specificity " of the individual plants used. A somewhat similar opinion appears to be held by Webber (189) in summing up evidence from stock-scion relationships among citrus species, for he states that congeniality is apparently dependent upon the similarity between the elaborated foods and by-products normally found in the two plants united. Haas and Halma (66) point out, however, that reactions such as starch accumulation above the union may be an effect rather than a cause, since the scion overgrowths accompanying these accumulations may be regarded as having an effect comparable to girdling.

A somewhat different conception of the biochemical reactions between stock and scion is propounded by Hafekost (67). He regards vigorous stocks as possessing protoplasm with a greater power of reaction than do dwarfing stocks of the same species, or in other words protoplasm able to form higher concentrations of cell-sap. With reference to the incompatibility shown to pear varieties by four vigorous clonal quince stocks selected at East Malling and referred to as D, E, F and G, he suggests that the cell-sap concentration in the stock rises during growth periods to an extent at which it becomes no longer possible for the pear scions to maintain exchange of materials with the stock without essential restriction and disturbance. For the same reason vigorous pear varieties such as Pitmaston Duchess tend to survive for a longer period on these quinces than do weaker pears and may even for a time grow strongly, because their protoplasm also possesses greater powers of reaction and adaptation to high concentrations of cell-sap. This principle, it is thought, might be used to predict the performance of varieties on different rootstocks before they were grafted.

If any conclusion may be drawn from this brief account, it is that hypotheses associating the causes of incompatibility with specific physiological differences between stock and scion must be regarded as purely speculative, but that there is sufficient evidence to suggest that further studies in this direction might provide interesting and useful information.

Precipitin reactions in relation to incompatibility

Precipitin or immunity reactions between specific proteins have been used since the end of the last century as a means of differentiating between various species of animals. More recently it was shown that specific precipitins could also be obtained from different plants, and this knowledge has served in certain quarters as a basis for re-examining the classifications used in the plant kingdom. Green (62) observes, however, that this work has not yet received general recognition, but quotes Raeder as stating that " the genealogy of plants established by means of sero-diagnostic reactions is gaining more and more recognition ".

The first investigation of immunological reactions in relation to the grafting of plants appears to have been that made by Rives (147) in 1923 in an attempt to determine whether the presence or absence of a precipitin reaction between tissue extracts might be correlated with the graft affinity of stock and scion in grapes. The particular object of his study was the variety Seibel No. 1020 which makes notoriously poor unions when grafted in any manner on Rupestris-du-Lot. His method was to take fragments of leafy shoots of the stock, grind them finely, mix with water, and after filtration inject the extract into a rabbit. The animal did not suffer

in any way and after twelve to fourteen days the serum was collected from it. It was then found that when one drop of the serum was added to ten drops of the aqueous extract from Rupestris a precipitate was formed in any time from twenty minutes to four hours depending on the temperature. Similarly, when the serum was added to extracts from several vine varieties which grow well on Rupestris precipitates in varying amounts were again produced, but when it was added to an extract from Seibel No. 1020 no precipitate appeared, regardless of whether this variety was growing on its own roots or as a scion grafted on Riparia. Rives concluded that if this sero-diagnostic method was always applicable it would be of great service in predicting the affinity between stock and scion.

Green in 1926 (62) conducted similar tests on a number of different species, again using the rabbit for immunization, but preferring to obtain his extracts from the seeds of the plants. Among extracts from five different *Citrus* species which are known to be easily intergrafted he found a uniform positive precipitin reaction with an immune serum obtained from one of them. Similarly among species of the sub-family Prunoideæ, also known to intergraft successfully, uniform positive reactions were obtained, but when the serum from this group was added to extracts from species of the sub-family Pomoideæ the results were negative. The conclusion is tendered that this absence of precipitin reaction between the two sub-families seems to coincide with the difficulty encountered in intergrafting their species. On the other hand Green has omitted to point out that apart from this very wide distinction his method does not appear to provide any indication of incompatibility which may exist between stocks and scions belonging to the same genus. Thus it is seen from his tabulated results that positive reactions were obtained between immune serum against *Pyrus Malus* (apple) and extract from *Pyrus communis* (pear) and between immune serum against *Prunus Amygdalus* (almond) and extract from *Prunus Armeniaca* (apricot) both of which combinations are well known to show but little graft affinity. This discrepancy in Green's hypothesis is noted by Proebsting and Barger (137) who conducted precipitin tests involving two plums, Beauty and Santa Rosa, both varieties of *Prunus salicina*, and the almond, *P. Amygdalus* (*P. communis*). The former of these plums makes an unsuccessful union with the almond, while the latter makes a good union. In their methods they followed Rives in utilizing vegetative parts of the plants to obtain extract, but in other respects their procedure resembled that adopted by Green. Each extract was tested with immune serum at the end of the period and also with normal serum at the beginning and at the end of the period. A distinct reaction was obtained in every case, a precipitate being formed in a dilution of 1 to 1,600, but it was impossible to differentiate between them. From this the authors conclude " that the uniformity of the reaction in reciprocal tests and in the comparative tests indicates that more refinements in procedure must be developed before slight differences can be demonstrated ".

The reactions so far investigated and described here have all been normal precipitin reactions occurring between the proteins of different species of plants, but in 1928 and subsequently the scope of the problem has been altered and expanded by a postulation of Kostoff's (110, 112, 113) that precipitins not normally demonstrated between plant extracts might be acquired through grafting. Working on intergeneric grafts of solanaceous plants he found that, when two species not showing any normal precipitin reaction were used as stock and scion and extracts from the leaves of each were tested against one another at five-day intervals, a precipitin reaction began to develop on about the twentieth day and increased in intensity up to the thirty-fifth day, after which it remained constant. This reaction he attributed to the mutual production of antibodies induced by the presence of antigens in the plants, and the relation of this production of antibodies to the development of external symptoms associated with incompatibility was demonstrated clearly in grafts of *Nicotiana glauca* on *Capsicum pyramidale*. The scions in this combination grew relatively well for the first four to five weeks after grafting, in some cases producing shoots 25 cm. long, a few of which even developed flowers, but after this period growth ceased and the scions began to die. From this it is pointed out that the inhibition of growth of the scions coincided with the period of greatest antibody production and most intense precipitin development, that is the thirty-fifth day noted above. Moreover, additional confirmation was obtained from the total failure to grow of new scions of *N. glauca* which were

grafted on to a *C. pyramidale* stock on which five scions of *N. glauca* had just previously died. The immediate failure of this second series of grafts is thought undoubtedly to be due to the presence of antibodies induced in the stock by the first series of grafts. The acquired immunity in such grafts was tested by precipitin reactions and the induced antibodies were found to be specific in certain species. On the other hand, heterogenetic or non-specific precipitins were also found, while in some graft combinations no precipitins were developed, and yet again in certain others, which showed relatively high normal precipitins, a decrease in precipitins following grafting was observed. These results suggest that it may not be the normal precipitin reactions occurring between plant proteins, but precipitin reactions induced by the act of grafting which may be responsible for the disorders associated with incompatibility. In other words Kostoff considers that " observed physiological interactions between scions and stocks accompanied by morphological phenomena in either symbiont are explicable by postulating antibody production."

Subsequent experiments made elsewhere have, however, thrown grave doubts on the existence of an exact association between acquired immunity and incompatibility in grafts. Chester (24) describes a disorder termed " graft-blight " which is manifested when lilac, *Syringa vulgaris*, is grafted on to certain privet stocks, *Ligustrum* spp. The chief undesirable factor in these combinations is discrepancy in the vigour of growth of the two graft symbionts caused or aided by the interruption of elaborated substances in their passage from the crown to the root-stock, but other factors are held to be clearly involved as well in the incompatibility, since in some cases the symptoms of nutritional deficiency and necrosis occur very early. Chester performed numerous precipitin and lysin reactions in these and other members of the Oleaceæ, and discovered that unlike the Solanaceæ no normal precipitins are present. By contrast, in tests of grafted lilac scions against various stocks it was found that in every plant suffering from graft-blight there was a strong acquired precipitin potency. Thus far these results confirm Kostoff's hypothesis, but in contradistinction to his findings the reactions in lilac-privet combinations were shown to be non-specific ; in certain cases of severe incompatibility the reaction was weak, while in others of mild incompatibility it was strong. Moreover, analogous or identical reactions were obtained with extracts from lilac leaves suffering from blight due to causes other than stock, and Chester suggests that this fact offers a hitherto uncontrolled source of error in plant immunology. He considers, therefore, that although the immunological technique may not be diagnostic of graft-blight, it may be regarded as diagnostic of a type of crown disease which develops when lilac is grafted on to privet and which may be due to a number of causes including incompatibility.

A repetition and extension of Kostoff's work on the Solanaceæ has also been undertaken by Chester and Whitaker (25, 26, 27, 190), and, although the technique adopted was essentially that used in the former's experiments, the results obtained have been very different. Seventy-five combinations consisting of representatives of ten genera and twenty-four species were tested for the presence of acquired precipitins after grafting, but not a single case was discovered in which the precipitin reaction was appreciably greater after grafting than it was prior to grafting, that is, than the normal precipitin reaction. Moreover, of the positive reactions after grafting 79% were found to be reactions between calcium and oxalate ions, while the remaining 21% were shown to be caused by a substance M, which is probably a protein, interacting with a less complex non-protein organic substance N. It is perhaps significant that Kostoff himself (111) found abundant accumulation of sand and groups of calcium oxalate crystals in the neighbourhood of the union. The existence of the calcium oxalate reaction is regarded as throwing considerable doubt upon the immunological significance of the " normal precipitin reaction " in plants ; and since, in addition, " acquired precipitin reactions " were not demonstrated in grafts involving the MN reaction any more than in those involving only the calcium oxalate reaction, the attribution of immunological significance to this particular reaction is likewise held to be quite unjustified in the light of present knowledge.

Chester and Whitaker (27) sum up the evidence from their own and other investigations by stating that the published immunological interpretations of precipitin reactions in plants are rendered untenable on the one hand because of lack of homology between the animal and plant reactions, and on the other because of the widespread occurrence in the plants tested of simple

non-protein reactions. They do not, however, eliminate the possibility of demonstrating immunological reactions from grafting in the future. Similarly Jones (105) states that " whilst Kostoff's work is most interesting and suggestive, the views advanced cannot be regarded as established. Other investigators have criticized his results and in some cases have failed to obtain like results. As emphasized by Krenke, while experimental investigation of immunity relations is most valuable and important, caution is required before transferring all the machinery of animal serological reactions to the plant kingdom."

Kostoff's conclusion that a specific mutual reaction occurs between the proteins and proteolytic enzymes in unrelated stocks and scions has also been questioned by Silberschmidt as recently as 1935 (165). In studies of grafts of herbaceous plants he found that the anatomical and physiological differences existing between grafts from the same, from related and from unrelated families were quantitative rather than qualitative. The processes of union were essentially the same in all cases, but the number and size of the groups of parenchymatous tissue connecting the two plants became fewer and smaller, the more remote the relationship of the plants. The more restricted the parenchymatous unions through which materials might pass from the scion to the stock, the greater was the congestion of nitrogenous materials above the union. This resulted in turn in a depletion of nitrogenous materials below the union, and thus increased the proteolytic activity of the sap passing from the stock to the scion. The more distant the relationship between stock and scion and the longer the time the union survived, the greater became the proteolytic activity of the sap supplied to the scion. No specific changes in proteolytic activity were found to occur in any of the grafts of unrelated plants, and it is, therefore, concluded that the differences between these and related plants in proteolytic influence of the sap are purely quantitative.

III. STOCK-SCION INCOMPATIBILITY IN RELATION TO INDIVIDUAL SPECIES AND VARIETIES OF DECIDUOUS FRUIT TREES

There is unfortunately as yet no means of determining in advance of experience what stocks and scions will be compatible or incompatible nor with what severity any incompatibility will be manifested. Thus Gardner, Bradford, and Hooker (52) state :—" The capricious occurrence of successful and unsuccessful unions follows no well-defined law ", and again Baltet (9) observes that " the results obtained up to the present can only be regarded as a matter of fact. No theory has yet been deduced from them except that kinds to be united by grafting must be of the same botanic order ". Likewise Chandler (21) writes :—" This subject has had little careful study. It is known from experience that only botanically related species can be successfully grafted or budded on to each other. On the other hand nearness of relation does not alone determine the degree of compatibility of stock and scion. . . . Something more than kinship is required for a good union." Among pear stocks, for example, some members of the same species, *Pyrus communis*, and all members of the closely related apple species, *Pyrus Malus* show less compatibility with scion varieties than do certain quinces which belong to a different genus, *Cydonia*. Even the rule that plants to be grafted must be of the same botanical family to make a successful union is not apparently without its exceptions. Sahut (156) states that Carrière grafted *Garrya eliptica* Dougl. on *Aucuba japonica*, thereby uniting members of different families, while Mitchurin (128) describes how his collaborator Jakovlev grafted lemon on to pear and provides a photograph of this combination after it has been growing for six months. Coulter and others (33) point out, however, that the achievement of graft unions between unrelated or distantly related plants does not seem so strange when it is remembered that successful grafting depends upon similarities between vegetative characters and that these are not necessarily correlated with the reproductive characters upon which plant relationships are based.

Moreover, the success or failure of a graft combination cannot be used as a certain indication of the result that will be obtained from the reciprocal graft. A good example of this is to be found in plums ; whereas most European plums, *Prunus domestica*, will prove fairly successful when top-worked on to Japanese varieties, *Prunus salicina*, the reverse procedure usually ends in failure (90). Similarly among herbaceous plants Roach (149) illustrates several cases in which the general behaviour and the compatibility of the original and the reciprocal grafts proved to be entirely different.

It may occur to some that the cytological constitutions of the components of a graft may have a bearing on their compatibility. In the only case seen, where a direct attempt was made to connect the two phenomena, the results were, however, in the negative (180). Apples alone were involved in this instance, but there is also a wealth of indirect evidence to show that in none of the other fruit species is the connexion between chromosome numbers and incompatibility any closer than that between botanical affinity and incompatibility. Thus as Hedrick (82) remarks, there is no way of predicting the behaviour of a combination in advance of trial beyond applying the knowledge that there must be some conformity in habit between stock and scion ; that the two must start growth at approximately the same time ; and that the tissues must be sufficiently alike to give proper contact at the union. The total inadequacy of these characteristics as a general guide to the performance of the majority of combinations and the existence of factors other than incompatibility which may produce superficially similar failures explains why in the ensuing sections experiences gained in grafting the major deciduous tree fruits have

had to be set out in some detail and with as much corroborative evidence as is available. These sections are compiled in the hope that they may be of assistance in providing indications of the compatibility or incompatibility of the numerous rootstocks in commercial use and under trial for the more important scion varieties. It should be remembered, however, that the performance of any given combination may sometimes be altered when it is grown in a different area. Perhaps the most striking instance of this variability is to be found in the complete failure of the sour orange as a citrus stock in South Africa and Java, although in many other countries it has been used extensively and successfully under a wide range of soil and climatic conditions. Webber (187) attempted to determine the cause of the failure in South Africa, but was unable to secure any suggestions that seemed feasible. Recent work by Toxopeus (173) in Java suggests that the cause of the failure does not lie in the sour orange itself, but in some toxic reaction of sweet orange, *C. sinensis*, scions upon the rootstock. Like Webber, however, he is at a loss to explain why the failure should occur in some localities and not in others possessing apparently identical soil and climatic conditions. On the other hand, his results also indicate that double-working, using a compatible intermediate, does not succeed, as in the case of deciduous fruit tree combinations, in preventing, or even in delaying, decline and death, and this may possibly mean that, in discussing regional variations in the compatibility of citrus grafts, we are dealing with a phenomenon of an entirely different nature. It is perhaps significant, therefore, that no such striking examples of variation appear to have been reported for any of the deciduous fruit species, but the fact remains that in different localities isolated rootstock trials have sometimes given very divergent results, and the possibility must, therefore, be borne in mind that a performance described from one area may not necessarily be that obtaining in another.

Rootstocks for apples

All common apple varieties and the great majority of apple rootstocks belong to a single species, *Pyrus Malus*. In the past, the stocks were divided very roughly into two groups, dwarfing stocks, comprising such types as " Paradise " and " Doucin " which were raised by vegetative means, and supposedly vigorous stocks which were raised from seed from " free " or " wild " crab apples. Within the last thirty years, however, stocks providing a complete range in vigour from very dwarf to exceptionally vigorous types (in their influence upon scion varieties) have been evolved at East Malling in England, and it would seem, therefore, that the best division of stocks would now be between clonal forms, raised vegetatively, and those still raised from seed. In Europe both forms are widely used, but in the United States most orchards are propagated on seedling " French " crab imported from European cider factories and to some extent in recent years on seedlings from commercial varieties and from local crab apples (22, 123, 194). In warmer regions, where the woolly aphis injures the roots of French cider seedlings, a common practice is to graft the resistant variety Northern Spy on to piece roots of the same variety, and then after one year's growth to bud the Spy with the desired scion variety. In areas where winter hardiness is a prime consideration the Siberian crab, *Pyrus baccata*, is sometimes used as a stock, or where the scion variety is itself hardy it may be grafted on to French seedlings and encouraged to form its own roots. The Prairie States crab, *Pyrus ioensis*, is also apparently used in some parts of North America (60).

As might perhaps be expected from the limited number of species involved very few cases of incompatibility, by comparison with those found in other fruits, have been reported. Of the interspecific grafts of apple on *P. baccata*, *P. ioensis* and other distinct species little information appears to have been published. Maynard (124) comparing three trees of yellow Siberian crab, *P. baccata*, budded with the variety William's Favorite with three ungrafted trees of the crab and three of the scion variety growing on its own roots, found that, although during the first season all the trees grew well, the budded trees subsequently made very little growth and by the tenth year all three had died. The fact that this stock is in commercial usage suggests, however, that lack of congeniality is not always shown in such marked degree. Roots of *P. ioensis* are claimed by Roberts (152) and Gossard (60) to give relatively poor stands of trees when bench grafted, but to produce satisfactory growth when budded. Drain reports in correspondence (46)

that seedlings of the native crab apples, *P. angustifolia*, *P. coronaria* and hybrids of this latter species make short-lived trees when used as stocks for such varieties as Delicious, Stayman Winesap and Golden Delicious. The buds take readily, but the tops die back within three or four years according to the variety. Rämer (153) quotes Howard as saying that pear, quince, and the American Mountain Ash, *Pyrus* (*Sorbus*) *americana* are also unsuitable as stocks for apples. Two varieties of apple, however, have been grown to sixteen years of age on pear stocks in New Mexico, and two other varieties have been successfully grown for many years on quince stocks in Uruguay. The course of the experiment with the pear stocks is recorded in annual reports by Foster and Garcia, successive Directors of the New Mexico Agricultural Experiment Station (131). The trial was started in 1907 to determine if pear roots, which are immune to woolly aphis, could be used instead of susceptible apple roots as stocks for apple varieties. The two scion varieties, Stark Delicious and King David, were budded on scaffold limbs of young pear trees, and the buds, on the average, " took " very well. Some of the pear branches, however, were left unbudded, and apparently were allowed to develop naturally throughout the whole period of the trial. The apple scions made good growth and most of them bore fruit each year. The union formed appeared to be strong, despite a tendency for the scion stem to outgrow that of the stock. No cases of complete failure are mentioned, but it is noted in the final report on the experiment in 1924 that the trees had not lived up to their original promise. The use of quinces as stocks for apples is described in a communication from Professor Urbina of the Facultad de Agronomia, Montevideo (182). He writes that quince seedlings have proved very satisfactory as stocks for the varieties Winter Banana and Colorada temprana (Early Colorada, a local variety of doubtful origin), producing small, precocious trees. No losses have occurred after planting out, and some of the trees are now over twenty years old. The only sign suggesting that any incompatibility may exist appears to be the tendency for Winter Banana on quince to produce a large swelling below the union. This cannot, however, be regarded as a very serious disadvantage, since this combination is now in use commercially on a large scale in Uruguay.

The majority of the cases of incompatibility described in apples refer to intervarietal combinations of *P. Malus* in which the rootstocks are of clonal origin. Hedrick (83), in comparing the merits and demerits of dwarf apple trees produced on Paradise stocks, and standard trees grown on vigorous stocks, considers that one of the disadvantages of the former is that the union made is inferior and that consequently more dwarf trees break off and are lost. On the other hand at East Malling, where clonal strains of both dwarf and vigorous stocks have been under trial for many years, Amos and others (2) state that no case of complete incompatibility has been found in any combination, and that, moreover, in the nursery there is no evidence at all even to suggest that it exists. They admit that Malling Nos. VIII and IX produce very small trees with swellings at the union, but question whether this dwarfingness, which is of a healthy nature, can be regarded as due to lack of compatibility. Trees on No. IX have been known to break off at the point of union, but breakages have been equally common in the stock stem itself, the brittle nature of the roots of No. IX being a well-known characteristic. Among the more vigorous clones, however, there are more definite indications that delayed incompatibility may occur in certain combinations, and in particular on Malling No. X the behaviour of different varieties has shown very marked variation. Hatton (76) describes how, while some varieties on this stock had made vigorous trees when five years old, the variety Bramley's Seedling from the first made little growth and appeared unthrifty on it, and he adds that No. X with certain scion varieties seems to afford the nearest approach to an incompatible apple stock. The trees in question have, however, all survived up to sixteen years of age. At Long Ashton Research Station, Spinks (168) also found one layered free stock selection to be very irregular in its performance when budded, and in correspondence with Amos and others (2) he writes that this stock and one other have given evidence of " delayed " incompatibility with several scion varieties. These two stocks among others from Long Ashton have also been under trial at East Malling where Amos and others have again found signs of incompatibility with the variety Lane's Prince Albert. They describe the trees as relatively unproductive, definitely dwarfed and showing a bronzing and purpling of the leaves in early autumn, while the bark

presents an unhealthy cracked appearance. On the other hand there have been no signs of premature death of the trees within a ten-year period, although the production of new wood growth has almost entirely ceased.

Malling selections are also under trial in the United States, but up to the present apparently only one case of incompatibility has been reported. Shaw (162) in Massachusetts has found that the variety Wealthy budded on Malling No. I, a fairly vigorous to semi-dwarfing stock which has always proved satisfactory in England, makes a tree so dwarfed as to be worthless, and in correspondence (163) he states that this may be regarded as a positive case of incompatibility. On the other hand this stock appears to be entirely congenial with McIntosh in the same trial and with Delicious and Starking in Pennsylvania (4). Among a number of clonal stocks raised in America there also appears to be but one clear example of uncongeniality, but this is of particular interest in being one of the most extreme cases recorded among apples. The stock in question is U.S.D.A. 227, a selected seedling of Northern Spy subsequently propagated by vegetative means. In trials described by Tukey and Brase (180) it has proved to be entirely unsuitable for McIntosh and Delicious,* the trees of both dying back in the second or third year after grafting, although with four other varieties no signs of incompatibility have developed. The significance of this result is possibly increased when it is recalled that certain varieties give unsatisfactory performances on Northern Spy itself. Hearman (81) discusses evidence from a number of sources which suggests that, while some of these failures may be attributed to unsuitable soil and climatic conditions or to the existence of inferior strains of the rootstock, it is clear that different apple varieties respond with distinctly different degrees of success when grown on a single superior strain and under suitable environmental conditions. Investigations on the influence of certain well-known varieties when used as stocks for other varieties have also yielded a few examples of incompatibility. Shaw (161) describes the roots of Oldenburg as proving very inferior to those of most other varieties, many trees having made poor growth or failed altogether on it after three years in the orchard. Red Astrachan at the same age was extremely dwarfed on Transcendent Crab, whereas McIntosh on the same root was very vigorous. In experiments on double-worked trees, outlined by Maney and Plagge (123) in Iowa, Virginia Crab, Hibernal and Haas have proved outstanding as intermediate stocks, making in general good unions with all commercial varieties. The senior author in recent correspondence (122), however, lists thirteen varieties out of some 250 tested, which have made relatively poor tops on Virginia Crab.

Little mention has been found anywhere of incompatibility being manifested when seedling stocks of *P. Malus* are employed, but this is hardly surprising in view of the very limited number of cases in which clonal stocks have proved uncongenial. Maney (122) writes, however, that Stayman Winesap has been found invariably to die out in Iowa, even after an ordinary winter, when worked on open pollinated seedlings of the very hardy and vigorous Mercer County Crab. In conclusion Amos and others (2) regard it as highly probable that a proportion of seedlings would always be incompatible, and consider that this may account for some of the unhealthy, dwarfed individuals which are often to be found among apple trees raised in this manner. On the other hand they doubt whether there will be any certain means of distinguishing between manifestations of rootstock effect and the milder symptoms of incompatibility, until the causes of the latter are established.

Rootstocks for pears

Hedrick (88) regards edible pears as falling into two well-defined groups: Occidental pears originating in Europe and north-western Asia; and oriental pears originating in eastern and north-eastern Asia. Both groups contain several species of *Pyrus*, but very few of these contribute anything to present-day cultivated varieties. Nearly all cultivated pears belong to one occidental species, *P. communis*, and the only other species in this group, which is in any way valued for its fruit, is *P. nivalis*, sometimes cultivated in parts of Europe for the production

* U.S.D.A. 227 has also been found to be incompatible with Grimes Golden in Maryland (A. Lee Schrader, correspondence, October 1936).

of perry. Among the oriental types several species are apparently grown in China and Japan for their fruits, but only one, the Chinese Sand pear, *P. serotina*, has given rise to any cultivated varieties in western countries, and these only in the form of hybrids with *P. communis* such as Kieffer and Le Conte.

For many years past the two major stocks for pears have been pear itself and quince, the latter being employed mainly for the purpose of producing a dwarf tree. In Europe both stocks are still widely used, but in the United States the quince, once fairly common, has fallen into disfavour, partly because a number of varieties have proved incompatible with it and necessitated the laborious process of double-working, but also, according to Tukey (174), because the trees are more difficult to grow in the nursery, demand closer attention in the orchard and because they often strike root above the stock and become standards. The great majority of commercial American orchards are therefore propagated on pear seedling roots. These are very largely imported from France, and hence are generally referred to as French pear stock. According to Chandler (22) the bulk of them belong to the perry or cider types of *P. communis*, but he suggests that consignments also probably include some seedlings of *P. nivalis*. Very considerable adulteration of *P. communis* by other species, including *P. nivalis*, has also been reported among European seedlings by Hatton (77) at East Malling, but, in so far as none of these species has been established as more incompatible with pear varieties than any of the others, and as in trials with seedling stocks no attempt has been made to differentiate between the different species present, the title *P. communis* will be used throughout this section to denote all pear stocks, whether seedling or clonal. There seems to be general agreement among American authorities that the French pear root would, in its better forms, possess all the attributes of a suitable commercial stock for pears were it to be less susceptible to the blight disease caused by *Bacillus amylovorus*. As it happens, however, the prevalence of this disease and the general lack of resistance shown to it by seedlings of *P. communis* has led in recent years to investigations with a number of other species, very largely of oriental origin, in the hope that a stock might be found to combine the desirable qualities of French pear with resistance to blight. Up to the present this search does not appear to have been very successful, because the relatively resistant or immune types discovered have all proved inferior to French pear in some other respects, and are therefore very unlikely to supersede it. In South Africa blight does not occur, and Davis (43) states that this obviates the need for finding stocks other than pears. Quinces are, however, used occasionally.

The pear itself as a rootstock

It has already been noted that pear seedlings are the commonest rootstocks for pears in the United States and South Africa, and that they are also widely used in Europe. Yerkes (194) reports that they make a strong, lasting union with all varieties, and other writers by omitting to find any fault in the growth and vigour of the trees would seem to concur in this opinion. The only cases which might suggest some slight degree of incompatibility are those of the hybrid pears (*P. communis* · *P. serotina*) on French pear seedlings. Bailey (7) states that Le Conte, Garber, Smith, Kieffer and other very vigorous growers of the Chinese type soon overgrow the French stock to a serious extent, and for this reason they are often grown from cuttings in the southern States. The French stock may, however, be used satisfactorily by producing long scions with the union set below ground, when the trees will quickly become own-rooted and will be able to dispense with the nurse root before complications arise. The variety Kieffer on pear seedlings is mentioned elsewhere by Tukey (175) who reports that in the north-eastern United States the combination is generally considered to make a poor union. He goes on to compare the growth of two rows of trees of this variety, the one on pear roots and the other raised from cuttings and therefore own-rooted. The trees on French roots were much less uniform and much less vigorous than the own-rooted trees ; they showed a conspicuous swelling at the union, and several died at an early age. More recently, however, Tukey and Brase (179, 180) describe a rootstock trial in New York State in which one of the combinations was Kieffer on pear seedlings, and these trees at six to seven seasons after budding showed satisfactory vigour and uniformity and no mortality.

Among the pear varieties of *P. communis* none appears to have been mentioned anywhere as incompatible with pear seedlings. The only evidence that some varieties may grow less satisfactorily than others on this stock comes from an account by Tukey (174) who lists six varieties which " succeed better on Angers quince than on pear " (see Table 2). He does not state, however, in what direction this superiority of the trees on quince might lie, and it seems doubtful whether the explanation is one of greater compatibility. Moreover Quinn (139) in South Australia describes a rootstock trial in which four of the varieties named by Tukey were compared on pear seedling stocks and Angers quince raised vegetatively. In each case the latter stock produced inferior trees, one variety in particular proving worthless upon it. It is, of course, possible that the Angers quince used by Quinn was of a different strain to any examined by Tukey in America, but the results are at any rate sufficiently clear to cast doubts upon the value of any generalization to the effect that certain pears succeed better on quince than on pear stocks.

Differences in the compatibility of different clonal varieties or strains of pear stocks with commercial pear scions have been studied at East Malling Research Station, England, by Hatton (77, 78) and by Amos and others (2). Between 1917 and 1921 some ten collections of seedling pear rootstocks variously named " free ", " seedling " or " wild ", were assembled and planted out for examination. It was found possible to divide these into four groups on differences in major characters, A, B, C and D, representing in all probability no less than four or five species or subspecies of *Pyrus* in section *Pyrophorum*, and within each group several selections were made and were referred to numerically as A1, A2, etc. These were subsequently established as clones by vegetative propagation and in 1923 eighteen clonal races were budded with the variety Dr. Jules Guyot. It is of interest to note that, while the majority of the clones have shown no signs of lack of affinity with this variety, two of them, A2 and C3, exhibited marked incompatibility after one year, the trees all ceasing to grow and ultimately dying, and a third selection, A3, has subsequently shown symptoms of possible delayed incompatibility.

Before passing on to a consideration of the quince stocks used for pears, mention must be made of the practice in some localities of the United States of top-working pears susceptible to blight on to a resistant body and framework stock. Chandler (22) mentions the variety Old Home as a highly resistant form of *P. communis* sometimes used as the interstock, and Reimer (142) regards this variety and Variolosa, which is apparently a hybrid between *P. Pashia* and *P. communis*, as the most promising among many types tested in southern Oregon as body stocks. Both make strong and desirable unions with the leading varieties grown in the district. Kieffer, *P. communis* × *P. serotina*, has also been used for the same purpose, and makes an excellent union with pear varieties when top-grafting is done on one-year-old wood. Finally Estella, a seedling of Kieffer and therefore of the same hybrid origin, has been found to make a good body stock for Bartlett and Beurré d'Anjou, but has proved uncongenial with Beurré Bosc.

Quince stocks for pears

Hatton (72) cites several early writers to show that various forms of quince (*Cydonia vulgaris*, formerly *C. oblonga*, and botanical varieties of this species) have for centuries provided the only important dwarfing stocks for pears in Europe, and in North America, although it is relatively of much less importance commercially, it is again the only species used widely for this purpose. The failure of certain varieties of pears to grow satisfactorily on some quinces has likewise been common knowledge for a long time past, and these failures which are now known to be associated very largely with incompatibility have been of sufficiently frequent occurrence to have induced a widespread adoption of the practice of double-working for certain combinations. The variety Bartlett is a good example of a pear which makes a poor union and fails to grow satisfactorily on the great majority of quinces, whereas the variety Beurré Hardy is an equally good example of the reverse ; a pear which takes kindly to quince stocks as a whole and is recommended as an intermediate for double-working incompatible types in such countries as the United States (22, 191) and South Africa (43). Beurré d'Amanlis is similarly mentioned by

Grubb (64) as the pear in all probability most commonly used for the same purpose in England. The value of varieties for use as intermediate stocks may, however, vary in different countries. Thus Gleisberg (56) reports that Duchesse d'Angoulême is considered to be suitable as an interstock in North America, but unsuitable in Germany.

Unlike the free or wild pear stocks, the quince stocks have for a long time been commonly raised by vegetative means, but, although from this it might be imagined that the behaviour of any particular quince with pears should be well known, this is not in fact the case. The reason for this has been clearly shown by Hatton and his co-workers at East Malling in England (2, 72, 75) and by such American authorities as Tukey (174) to lie in the serious mixing of quince types in commercial nurseries, so that the parent stocks from which the clones arise are themselves by no means uniform.

Among the named varieties of quince the free-growing Angers quince when true to type is considered by Tukey to be the most satisfactory form known at present in the United States, and it is also the one variety found worthy of mention by Bailey (7) who refers it to *Cydonia oblonga* (now *C. vulgaris*). Both authorities use it as the basis upon which to give lists of pear varieties which do well or fail when worked direct on quinces, but it is to the work at East Malling to which we must turn in order to obtain a true picture of the differences in affinity shown by the various quince types for pears, and to realize the serious consequences attendant upon mixing these types in the nursery.

Hatton (72, 75) describes how a collection of quinces was assembled at East Malling and seven distinct types subsequently isolated and propagated as clones. Four of these types represented selections from named commercial stocks, but owing to the great confusion existing in the nomenclature used by different nurseries they were merely assigned the letters A, B, C and D. The degree of confusion may be gauged from the following facts :—Type A, which appears to be the true Angers quince and is undoubtedly the type in most frequent use in English nurseries, has been found mixed with other forms of quince and has also been discovered under the name of " Fontenay " ; Type B, which is also fairly widely used, arrived under the name of " Common " but has also been found under such names as " Angers " and merely " Quince " ; Type C arrived as " Angers ", but is most certainly a different type, and does not appear to have been employed at all widely ; while lastly Type D was selected from a very mixed batch of stocks referred to as " de Fontenay ", but has also been found under the name of " Common " quince. Whether these four types belong to the main species, *Cydonia vulgaris* or to one or other of its botanical varieties is not stated, but as they seem to be quite distinct from types representing any of these varieties they are in Table 1 (giving lists of incompatible and compatible combinations of pears) all grouped under the heading of *C. vulgaris*. The three other quinces included in the selections were types of superior vigour normally grown for their own fruits and not as stocks. Although apparently accurately named they were denoted by the letters E, F and G for purposes of uniformity. Hatton cites several early writers who singled out Type E, the Portugal quince, *C. vulgaris* var. *lusitanica* as a suitable stock for pears, but adds that there is no recent record of its use for this purpose. Type F, the apple-shaped quince, *C. vulgaris* var. *maliformis*, and Type G, the pear-shaped quince, which is apparently *C. vulgaris* var. *pyriformis*, do not seem to have been used to any extent as stocks either in the past or in recent times.

Clonal races of these seven quinces have been worked with a number of different pear varieties, and the results obtained indicate that, while they could roughly be divided into two groups, safe and unsafe, on a basis of their compatibility with pears as a whole, peculiar varietal differences were also apparent among the pear varieties. In general, however, and with the exception of two varieties, Dr. Jules Guyot and Reine des Poires, all pears are reported by Hatton in a recent paper (78) and by Amos and others (2) to be successful on Types A, B and C, whereas on the fourth commercial stock Type D and on the three named quinces E, F and G they have exhibited a very general incompatibility. The manifestations of this incompatibility have in the main been in delayed forms rather than in immediate failure in the first year after budding ; with most varieties and in the majority of seasons the percentage take of buds has been good and the number of maiden trees produced has been satisfactory, but at the end of the

first year in the nursery or subsequently in the plantation the trees on these four stocks have with few exceptions remained very stunted and shown a high mortality. Seasonal contrasts have sometimes been marked. One of the early batches of Pitmaston Duchess, for example, produced five-year-old trees of very fair vigour on Types E, F and G, whereas in other years the trees have often failed within one or two seasons. Another interesting exception is provided by sixteen Conference trees, which were budded on to Type G in 1923, and are at present, when fourteen years old, still healthy. In a similar batch of sixteen trees, budded two years earlier than this, thirteen trees died within the first two seasons and the remaining three trees died a few years later. Other varieties show similar though usually less well defined seasonal variations in behaviour, and it would seem that no very hard and fast rule can be laid down as to what exact form incompatibility will take in any one pear variety on a particular quince. Hatton (78) considers, however, that there is sufficient evidence to show that out of the seven quince clones tested only the three, A, B and C, merit further consideration from the points of view of either the nurseryman or the fruit grower.

Three further quince types, Champion and Meech's Prolific, both large-fruited varieties, and an unnamed type referred to as East Malling C1, have since been tested as possible stocks for Dr. Jules Guyot and Reine des Poires, the two pears which have proved unsatisfactory on all the other quince stocks. Amos and others (2) report, however, that they have proved no better than the Angers quince, Type A, producing trees that were, if anything, more dwarfed and that showed a larger mortality at an early age.

Oriental pear stocks

As was noted at the beginning of this section the susceptibility of French pear roots to blight in the United States has led in comparatively recent years to a search for other stocks which might prove resistant to this disease and at the same time produce satisfactory trees. The types selected for this purpose appear to belong almost exclusively to the oriental group of *Pyrus* species, and some of these have now been tested on an extensive scale, notably by Reimer (142) in Oregon.

P. serotina, the Chinese sand pear, was introduced as a seedling stock of supposedly greater resistance both to blight and to the pear-root aphis. Yerkes (194) states that it has been widely used and that nearly all varieties make good unions and growth with it, whilst Reimer (142) goes even farther than this and claims that almost every known species of *Pyrus*, including all the leading varieties of *P. communis* in Oregon, will make strong unions and satisfactory growth with this stock. In England a few layered, clonal selections of *P. serotina* have been budded with the pear variety Dr. Jules Guyot at East Malling, and Amos and others (2) report that up to six years old the trees have shown no signs of incompatibility. The very general congeniality of this species with pear scions is confirmed by Johnston (104), but both he and Chandler (22) note that with Bartlett and probably many other pears the use of this stock promotes a serious physiological injury at the blossom end of the fruit known as " black-end " which practically renders it valueless. As regards the influence of *P. serotina* on the growth and vigour of scion varieties the only adverse criticism discovered is in the description of a trial with three pear varieties by Tukey and Brase (179, 180) in New York State. Of the three varieties only Kieffer, one of whose parents is *P. serotina*, had made satisfactory trees by the seventh year after budding. The trees of the other two pears, Bartlett and Seckel, which are both pure *P. communis*, were distinctly weak at the same age, and there had been some mortality in each case. No suggestion is made, however, as to whether or not this failure is considered to represent a form of incompatibility.

P. Calleryana is another species originating in central China which has been used to some extent in recent years as a stock for pears in the United States. Yerkes (194) states that the majority of varieties make even more vigorous growth upon its seedlings than they do upon those of French pear, and Reimer (142) describes it as making an apparently congenial union with the leading pear varieties in Oregon, producing splendid growth in trees six years of age. In England, too, layered clonal selections of this species worked with Dr. Jules Guyot are described by Amos and others (2) as showing no signs of incompatibility at six years old, the

trees behaving like those on the stronger pear stocks. Very unsatisfactory results have, however, been obtained both by Johnston (104) in Michigan and by Tukey and Brase (179, 180) in New York State. The former found that trees on *P. Calleryana* exhibited great variability in growth, some being vigorous and very promising and others poor and worthless, while a high proportion of trees in the orchard had to be replanted. In New York seven-year-old trees of Bartlett, Seckel, Beurré d'Anjou and Kieffer were in all cases weak and tender, and some mortality was again evident. Both authorities conclude that seedlings of *P. Calleryana* are, at any rate in their present unselected form, much inferior to those of French pear, but neither makes any definite assertion that the reason is one of incompatibility. Chang (23), however, comparing the percentage take of buds of Bartlett and Kieffer on this stock at Chekiang in China, found the proportion to be relatively lower with the former at all times regardless of external conditions such as climate, and concluded that this represented a manifestation of partial incompatibility between Bartlett and the stock.

P. ussuriensis is mentioned by Yerkes (194) as another oriental pear, which has given evidence of desirable qualities as a stock, but Reimer (142) points out that a distinction must be drawn between two types of seedlings:—the first arising from seed gathered from wild trees in China, and on which pear varieties rapidly outgrow the stock, eventually breaking off at the union ; and the second arising from seed of certain named, cultivated varieties, which are much more rapid growers. Where undersized trees of the latter are discarded in the nursery it is suggested by trials in Oregon that they make congenial unions and satisfactory trees. Johnston (104) confirms the different behaviours of the wild and cultivated seedlings, but adds, however, that, as it is practically impossible to distinguish the seed from the two sources, the utilization of this stock is a somewhat hazardous matter. In New York State, Tukey and Brase (179, 180) found that the variety Kieffer made a large and vigorous tree on *P. ussuriensis* at seven years after budding, but that Beurré d'Anjou, Bartlett, and Seckel produced rather weak trees, some of which died. The source of the seed is not, however, mentioned.

P. betulaefolia is mentioned only by Tukey and Brase (179, 180) and by Reimer (142) as a seedling stock under trial for pears. The latter reports that the six leading commercial varieties in Oregon had by the time they were six years old made very satisfactory growth on this stock, slightly surpassing in vigour the same varieties on the standard French pear stock. With some varieties the union was perfect, but in others a slight enlargement developed below the union, and in one case, that of Comice, the scion tended to overgrow the stock. It is thought, however, that if the differences become no more marked as the trees become older the union will prove to be satisfactory. In trials in New York State, Tukey and Brase also found that trees of Bartlett, Seckel and Kieffer on this stock made outstandingly vigorous growth up to seven years from budding and in addition bore fruit at an early age. In contrast to results obtained in Oregon with the variety Beurré d'Anjou, however, this pear proved uncongenial in their experiment, the trees being weak and unsatisfactory and some of them dying. In general, however, they consider that *P. betulaefolia* is the only oriental species showing sufficient promise to merit further trial in the eastern United States, but they issue a warning that the factors of incompatibility and black-end disease may yet develop as the trees under investigation become older.

P. serrulata is a species intermediate between *P. serotina* and *P. Calleryana*. Reimer (142) reports that seed collected in China gave rise to very variable seedlings ranging from types identical with *P. Calleryana* to types typical of *P. serotina*. Their resistance to blight proved likewise to be very variable, and they cannot be recommended as blight resistant stocks, although some types may be of value if kept true to type by propagation from root-cuttings. They have not, however, been top-worked with any of the standard varieties in Oregon, and so it cannot yet be said whether the unions formed will be congenial, but in a trial at East Malling in England Amos and others (2) report that layered selections of this species, budded with Dr. Jules Guyot, produced trees which at six years old were very similar to those on the stronger *P. communis* stocks and gave no indication of any lack of compatibility.

P. Koehnei is stated by Reimer (142) to be a native of tropical and semi-tropical areas in extreme southern China, and is probably only a form of *P. Calleryana* (141). The leading

Oregon pear varieties budded on to this species made vigorous growth and at about eight years old the unions appeared to be entirely satisfactory.

Other stocks used occasionally for pears

The apple, *Pyrus Malus*, is mentioned by Bailey (7) as a species sometimes used as a stock for pears, though the trees produced are short-lived. Where pear stocks are not available, apples may be substituted, the union being set low so as to encourage own-rooting when the nurse stock fails. Old apple trees may likewise be sometimes top-worked with pears which may bear large fruits for a few years (192). Davis (43) in South Africa also notes that pears grafted or budded on to apples may flourish for a time, but agrees with Bailey that the trees are rarely long-lived. Bradford and Sitton (17), studying defective graft unions in the two species concerned, class pear on apple as one of the most uncongenial among combinations which will unite at all, and both they and Proebsting (135) describe in some detail the internal defects which develop at the union and result in the death of the tree or the breaking apart of stock and scion within a very few seasons.

Hawthorn or whitethorn, *Crataegus Oxyacantha*, raised from seed is mentioned by Baltet (9) as a species occasionally used as a stock for pears in France, and Bailey (7) also notes that good dwarf trees are often reported on thorn in the United States, although he omits to state whether by thorn he means the same species. Hedrick (82) writes that pears unite readily with hawthorn, but Burbidge (20) claims that the combination is short-lived and little better than pear on apple. The only definite record of the performance of hawthorn comes from East Malling in England, where Amos and others (2) describe trees of Fertility pear grafted on to seedlings of *C. Oxyacantha* as being exceptionally vigorous up to nine years old. Three selections of hawthorn were also tested in the nursery with Dr. Jules Guyot and Reine des Poires. With the former as scion a certain number of small one-year-old trees were obtained, but with the Reine des Poires all three selections proved completely incompatible.

The mountain ash, *Pyrus Aucuparia* is sometimes used as a stock for pears on sandy soils, but according to Bailey (7) is of little consequence. At East Malling trees of Fertility on seedlings of this species made stunted growth (2).

White beam, *Pyrus Aria*, and wild service, *P. Torminalis*, were grafted with Fertility at East Malling. Amos and others (2) report that the trees produced were stunted, but that ultimate effects could not be gauged owing to the intervention of scion-rooting.

The percentage take of grafts of two pear varieties, Bartlett, *P. communis* and Kieffer, *P. communis* × *P. serotina*, on various other species was investigated by Chang in Hangchow, China (23). The species included *Pyrus Calleryana* and *P. betulaefolia* in section *Pyrophorum* ; *Pyrus baccata, P. baccata manshurica, P. floribunda* and *P. triflora* in section *Malus* ; and *Cydonia sinensis* (*Chaenomeles chinensis*) and *Cydonia cathayensis* (*Chaenomeles lagenaria*) in section *Eriolobus*. Kieffer on the whole showed a much higher percentage take than did Bartlett throughout the series, but the proportions of grafts uniting remained approximately the same for both varieties whether the stock species was a member of *Pyrophorum*, of *Malus*, or of *Eriolobus*.

Rootstocks for plums

As will be seen from an examination of Table 2 there are a large number of species and varieties of *Prunus*, which have at one time or another been used as rootstocks for the various types of cultivated plums, and which have exhibited in greater or less degree a measure of incompatibility with the scion varieties worked upon them. Almost every form taken by incompatibility, from the complete failure of buds to " take ", to the production of a rather stunted and short-lived tree appears to be represented in the list of stock-scion combinations tested. In the account which follows an attempt is made to summarize the data available on this problem with particular reference to Great Britain and the North American continent.

The plum varieties grown in Great Britain belong principally to the two species *P. domestica* (plums and prunes) and *P. insititia* (damsons and mirabelles) and also to a small

extent to *P. cerasifera* (the myrobalan or cherry plum). A collection of rootstocks from Western Europe, assembled at East Malling Research Station in 1921, was found by Hatton (73) to consist of members of the same three species, but in addition included Marianna, apparently a hybrid between *P. cerasifera* and *P. Munsoniana*, a few specimens of *P. spinosa* (sloes and bullaces) and a number of seedlings, probably of hybrid origin, which could not definitely be assigned to any specific group. These species were represented by several varieties, which, placed roughly in order of popularity, were as follows :—Mussel, Brussels, Common Plum, St. Julien, Black Damas, Myrobalan, Marianna, Brompton, mixed seedlings of *P. domestica*, Kroosjespruim, and *P. spinosa*. Prior to the initiation of this study no attempt seems to have been made to classify and describe these types accurately. Mixtures, different strains, and misnomers were found to be common, and the lack of accurate data is held to have resulted not infrequently in wholesale failure in the nursery bed, due apparently to cases of incompatibility between stock and scion, which have since been revealed (2, 73, 74, 80), and also to the planting of trees on unsuitable or undesirable root systems (73).

The botanical study of these varieties (73) has led to the separation of several distinct strains or types within a number of the varieties. Of the stocks previously raised by vegetative means it was found possible for example to subdivide the very mixed Mussel group into Common Mussel, Broad-leaved or Shiny-leaved Mussel, and Narrow-leaved or Bastard Shiny Mussel. Of the stocks raised from seed four selections, referred to as A, B, C and D, each of Myrobalan, St. Julien, and Black Damas were made, and these will subsequently be kept true to type by vegetative propagation.* The St. Juliens included a particularly wide range of types, some being thorny and others spineless, and their fruits varying in form from that of a typical damson to that of a greengage (79). The fact that such selection of distinct types was possible may go a long way towards explaining the variable behaviour of scion varieties budded on to mixed seedlings. A very clear instance of how great this variation in stocks may be has been shown by a cytological comparison of St. Julien A and St. Julien B. According to Moffett (129) the former is a typical member of *P. insititia* in which the somatic chromosome number, 2n, equals 48. St. Julien B, on the other hand, has $2n = 40$, and it is considered very likely to be a hybrid seedling arising from a cross between *P. insititia* ($2n = 48$) and a tetraploid form of *P. spinosa* ($2n = 32$). Of the clones under trial, Myrobalan B, St. Julien A and B, and Black Damas C are regarded as promising.

Cases of incompatibility have been found to occur in all the species mentioned, but according to Amos and his co-authors (2) there is at present no reason to suppose that the

* The variable performances of these clonal stocks when budded with the plum varieties, Victoria and Czar, may be gauged from the following notes based on a recent paper by Hatton (65) and on unpublished nursery data collected at East Malling :—

Myrobalans B, C and D :—Both varieties have shown fair to high % bud takes, and have grown and cropped well up to 11-13 years old. Slight differences have been mainly in favour of trees on B.

Myrobalan A :—Both varieties have again shown fair % bud takes. The growth of Victoria to 13 years was nearly as good as on B, but its cropping was significantly lower. Czar up to 11 years old proved distinctly inferior in both growth and cropping to trees on B.

Myrobalan E (a continental type known as Myrobalan blanc, added subsequently) :—Czar proved significantly less vigorous and lower in cropping than on B.

St. Julien A :—Czar gave satisfactory % number of maiden trees, and showed medium growth and cropping to 9 years. Victoria gave a good % take of buds, but had a high mortality in the nursery and the remaining maiden trees were dwarfed.

St. Julien B :—Czar gave a satisfactory % number of maiden trees, grew more vigorously and cropped better than the trees on A. Victoria gave a low % bud take, but all the trees formed grew vigorously.

St. Juliens C and D :—Both Czar and Victoria gave satisfactory nursery performances, but Czar subsequently made weak, low-cropping trees.

St. Julien E (added subsequently) :—Czar gave 100% bud take and 80% maiden trees. Victoria gave 0% bud take.

Damas A :—Czar gave 100% bud take and 100% maiden trees, and in growth and cropping to 9 years old exceeded comparable trees on Myrobalan B. Victoria, however, gave 0% bud take.

Damas C :—Both Czar and Victoria showed satisfactory nursery performances, and the trees of Czar grew with moderate vigour and cropped fairly well up to 9 years old.

Damas D :—Czar showed fair % bud take, no mortality, and grew vigorously in the nursery. Victoria gave a higher % bud take, but showed some mortality and grew weakly in the nursery.

rootstocks belonging to one species are more likely to show lack of affinity with scion varieties than are those belonging to another. With varieties on the other hand, and apart from considerations of different strains, some rootstocks have been found more liable to show incompatibilities than have others. Thus, in 1923, Hatton (74) stated that certain stocks such as Pershore, Brompton (both *P. domestica*) and Myrobalan (*P. cerasifera*) are generally speaking " good mothers " for Domestica and Insititia plums, that is they take the buds or grafts of most varieties well and make good maiden trees. On the other hand stocks such as Common Plum and Brussels (both *P. domestica*) and the Broad-leaved Mussel (*P. insititia*) seem to show what can only be described as incompatibilities with certain varieties of plums and damsons. In certain cases they may make good stocks, but in others either the buds fail to " take " in any quantity, or sometimes established trees break away at the point of the union. In a later paper Hatton and others (80) note that the same tendency is to be found among scion varieties. Whereas Victoria, for example, is compatible with the great majority of rootstocks, Czar frequently shows lack of affinity with many types.

The same authors point out, however, that not all cases of failure to obtain a tree can be explained by incompatibility between stock and scion. Experience has shown, for instance, that to obtain the best results in budding Brussels with any variety the operation must be done early, because this stock is very apt to dry out. In the same way there is evidence to show that the failure of buds of Jefferson's Gage to " take " is due to a peculiar development of the node which causes manipulative defects. Furthermore it has been shown in some cases that if grafting is substituted for budding the initial difficulty of starting a tree may be largely overcome. Seasonal differences affecting the percentage take of buds from year to year are noted by Amos and others in a recent paper (2), in which they state that it must not be assumed that because a particular combination appears to give a poor result in one or two seasons this result is necessarily due to incompatibility. Despite the existence of factors such as these, however, there remains strong evidence that whatever the conditions of budding or grafting may be, certain combinations of plums will always exhibit a comparative failure. The combinations, which at East Malling have been found to fail through apparent incompatibility, are listed under their stock species in Table 2 together with notes as to their behaviour.

In North America the position is considerably complicated by the addition of several other species of *Prunus*, both as stocks and scions, and by the almost universal practice of employing seed for raising stocks. An examination of the literature reveals that, although certain species are commonly found to be incompatible with each other, there are few quantitative data to indicate the exact nature or importance of incompatibility among plums as a whole. The only evidence relating to stock-scion affinities as between known varieties appears to be that obtained in cases where orchard trees have been top-grafted.

Turning first to California it would appear that the cultivated plums belong mainly to the two species, *P. domestica*, referred to as European plums and prunes, and *P. salicina* and hybrids of this species, referred to as Japanese plums. As regards rootstocks Wickson (191) states that plums on their own roots generally resulted in an orchard full of suckers, and to avoid this they used to be worked on to peach seedlings wherever the soil was suitable for this stock. As some varieties did not take kindly to peach, double-working was also common. The adoption of the myrobalan or cherry plum, *P. myrobalana* or *P. cerasifera*, as a general stock for plums and prunes finally did away with both suckering and double-working. Between 1923 and 1929 a census was taken to show the proportional numbers of different nursery rootstocks used for prunes, *P. domestica*, and this is quoted by Hendrickson (89) as follows :—

Myrobalan	54·5-75·4%
Peach	16·5-38·2%
Almond	2·3- 9·6%
Apricot	1·0- 5·7%
Davidiana	a few trees in each of several years.

According to Kinman (107) much the same order would appear to hold good throughout the Pacific States as a whole. He claims that the Myrobalan plum and peach are by far the most

common nursery stocks for plums, although the almond is used in some localities, notably in California, whilst Marianna and apricot are also used occasionally. In New York State Hedrick (84) observes that Myrobalan is again the commonest, as well as the most satisfactory, general stock for Domestica, Insititia and Salicina plums. In some of the colder regions of North America the principal plum varieties and stocks have been derived from native species such as *P. americana*, *P. hortulana*, and *P. Munsoniana*.

Much of the information relating to American plums stock affinities which is also assembled in Table 2 was obtained from papers by Heppner and McCallum (90), and Kinman (107) who describe the results of top-working a large number of species and varieties of *Prunus*, and from a paper by Hedrick (84) who describes a rootstock trial in New York. From the reports of their studies there can be little doubt but that many combinations show forms of incompatibility similar to those found for plums in England. It might be noted at this point, however, that in some of the combinations listed in Table 2 the only evidence suggesting lack of affinity is contained in such remarks as " makes unsatisfactory trees ", " produces questionable results ", etc., and it is felt that, in view of the existence of other factors which were found by Hatton and others (80) to produce failures, and where corroborative evidence or more explicit descriptions are not available, such descriptions must be regarded with considerable caution. On the other hand there seems to be general agreement between American authorities as to the behaviour of plum species on rootstock species as a whole and their opinions may be summarized briefly as follows :—

1. Myrobalan, *P. cerasifera*, is described by Yerkes (194) and Hedrick and others (85) as the stock in most general use throughout the United States and as one which makes strong, lasting unions with the principal varieties of plums. In California it appears to be congenial with the majority of Domestica and Salicina varieties (90, 107), and in New York State is considered to be the most satisfactory stock for Insititia plums as well as for the two species mentioned above (84). Hedrick points out that it remains to be seen whether these several species are long-lived on Myrobalan, whether perhaps some untested varieties of these species may show lack of affinity with it, and whether or not some strains of the stock may prove to be better than others.

2. Marianna, *P. cerasifera* × *P. Munsoniana*, tested by Hedrick (84) in New York State proved to be the best stock for two varieties of *P. Munsoniana*, Wild Goose and Pottawattamie, and for two varieties of *P. hortulana*, Forest Garden and Wayland. Its behaviour with the three commoner species of cultivated plums was not so satisfactory as that of some other stocks, but no definite assertion of incompatibility is made.

3. European plums and prunes, *P. domestica*, are not very commonly used as rootstocks in the United States, but a number of trees in California have been top-worked successfully with Japanese varieties, *P. salicina* and hybrids of this species. Clyman, Diamond, French Prune, Giant, Sugar Prune and Tragedy Prune are cited as making particularly good unions and trees. Most European plums are compatible when worked with varieties of the same species, but California Blue is an outstanding example of a Domestica plum which has proved to be a failure, either as stock or scion, in nearly every case, irrespective of whether the other component was a Domestica or Salicina variety. Bailey (7) notes that native American plums are occasionally propagated on Domestica seedlings.

4. St. Julien and Black Damas, *P. insititia*, are the only varieties of the species mentioned as stocks (7). According to Yerkes (194) the former is sometimes preferred to other types as a stock for European plums, and in the New York trials made by Hedrick (84) it proved, in general, second to Myrobalan as the best stock both for Domestica and for Insititia varieties. It is possible, however, that, as in England, the name St. Julien may cover a wide range of types in North America, since Waugh (183), writing in Vermont in 1900, places local St. Julien stocks in the Domestica group.

5. Peach, *P. Persica*, appears to be considered by all authorities to make good stocks for almost all Japanese plums, *P. salicina*, in both the eastern and western U.S.A. Where there is no danger of winter killing, Hedrick (84) considers that it may prove to be as satisfactory for these plums as is Myrobalan. Kinman (107) observes, however, that it has not yet been determined

whether all varieties of peaches would be equally desirable for purposes of top-working. Both Heppner and McCallum (90) and Kinman regard peach as an uncertain stock for Domestica plums. A number of varieties show some measure of incompatibility, and of these Diamond and Grand Duke are instanced as making perhaps the poorest unions. Even these varieties may, however, continue to bear profitable crops over a considerable term of years after grafting, and from this it would seem that the lack of affinity between the species is not very marked.

6. Almonds, *P. Amygdalus*, are sufficiently congenial with some Salicina and Domestica plums to make good trees, but in other cases failures have been recorded. Heppner and McCallum in a second paper (91) state that the variety of almond which is used as the stock may have a decided effect upon the compatibility existing between plum and almond. They describe the case of an almond orchard composed of six varieties which was top-grafted on to Sugar Prune, a Domestica variety. Within three years practically all the grafts on four of the varieties, I.X.L., Peerless, Drake and Nonpareil, had died, whereas those on the other two, Eureka and Ne Plus Ultra, were in good condition after seven years. The existence of different strains, or some other obscure factor, is also suggested by Kinman (107) to be a possible explanation of the variable results obtained in using almond stocks. He cites the case of two trees of Agen (French) Prune top-worked on to almond, in which one tree developed faulty unions, and the other appeared entirely congenial, and adds that other similar instances are matters of observation.

7. Apricots, *P. Armeniaca* are, in general, considered to be poor rootstocks for both Domestica and Salicina plums, and only a few varieties do comparatively well on them. One of these latter appears to be Sugar Prune, and Howard (96) contrasts it with French Prune which sooner or later almost always parts company with the apricot stock at the point of union.

8. Japanese plums, *P. salicina* and hybrids of this species, only appear to require consideration in so far as trees may be top-worked with other species. Heppner and McCallum (90) state that they cannot, as a general rule, be said to succeed as stocks for any of the Domestica plums.

9. Americana, *P. americana*, stocks are of particular interest only where resistance to cold is an important consideration. According to Budd (19) two distinct races must be distinguished, the one small in growth and fruit and virtually valueless as a stock, and the other to which the cultivated varieties of the species belong, which provides the best stock in western districts for native plums and certain prunes. Yerkes (194) also states that it is regarded as especially good for native varieties and that it will unite with European and Japanese plums, but he adds that it is not so certain in this respect as is Myrobalan. According to Waugh (183), however, the union made with Domestica plums is usually poor. Hedrick (84) considers that in New York State it is suitable only for varieties of the same species, but he also admits that where hardiness is a primary consideration it might be used for varieties of other species. Bailey (7) states that it makes a good dwarfing or semi-dwarfing stock, the bud or graft usually growing luxuriantly for two or three years and thereafter rather slowly, while Alderman recently in correspondence (1) describes it as an excellent stock for new hybrid varieties in Minnesota, if the bud is inserted low, but unsatisfactory for top-working owing to the tendency for scions greatly to overgrow the stock.

10. Among minor species, *P. Munsoniana* and *P. angustifolia* were mentioned by Bailey (7) in 1920 as good stocks for dwarf or intermediate trees, and the sand cherries *P. pumila* and *P. pumila* var. *Besseyi* (*P. Besseyi*) were claimed by the same writer to show promise experimentally as dwarfing stocks. From the lack of subsequent information, however, it does not appear that their adoption as rootstocks has been at all widespread. *P. Mume*, the Japanese apricot, is under trial in California as a stock resistant to crown gall caused by *Pseudomonas tumefaciens*, but according to Smith (166) it has shown distinct signs of incompatibility with four Japanese varieties and with three out of five European plums. The union with Clyman, *P. domestica*, and Myrobalan, *P. cerasifera*, appears, however, to be strong, and it is suggested that these two plums should be tested as intermediates for double-working. Chabot, *P. salicina*, Milton, *P. Munsoniana* × ?, Newman, *P. Munsoniana*, and Green Gage, *P. domestica*, are all reported to have grown satisfactorily on Wayland, a variety of *P. hortulana* in Vermont (170).

The question of rootstocks for plums in South Africa is discussed briefly by Davis (43). Both Japanese and European plums are cultivated, and the following stocks are found in use :— peach, peach-almond, almond, apricot, Marianna plum and Myrobalan. Of these the peach is probably the commonest, the hardy, adaptable, South African yellow peach being the most popular, especially for Japanese plums. Apricots are considered to make excellent stocks for both prunes and Japanese plums except in unsheltered positions where strong winds may result in trees snapping off at the unions. Marianna is in general use in Natal. Myrobalan, one of the earliest introductions, has proved to be a most useful stock, and is held to be undoubtedly the best for Domestica plums and prunes on damp or heavy soils. It has also been tried for some Japanese plums, but with the exception of a few varieties such as Kelsey has shown a lack of affinity and proved unsuccessful. The peach-almond and almond have been used only occasionally.

From Australia the only information discovered on plum stocks is that in papers by Cooke (31, 32) who describes a rootstock trial in New South Wales, and by Davey (42) who regards Myrobalan as the best stock in Victoria. In the trial conducted by the former, six varieties of *P. domestica*, three being plums and three prunes, were worked on to four different rootstocks. At ten years old the trees on apricot and peach were largest in every case, those on Myrobalan came next, and those on Marianna were the smallest. For plums the author considers the latter stock to be definitely unsuitable owing to the weak type of growth produced, and for prunes its value is held to be doubtful.

The position with regard to plum rootstocks summarized

An examination of the literature reviewed in this section and of Table 2 would appear to lead to the following conclusions.

1. The great majority of cultivated plums in the British Empire and in the U.S.A. belong to the three species *Prunus domestica*, *P. insititia*, and *P. salicina* (with hybrids).

2. The rootstocks in most general use belong to *P. domestica*, *P. insititia*, *P. cerasifera*, and *P. Persica*. When top-working is also considered *P. Amygdalus* and *P. Armeniaca* may assume a position of some importance.

3. Interspecific incompatibility has been found to occur in all types of combinations ranging in its frequency and degree from very slight in cases where Myrobalan, *P. cerasifera*, is used as a rootstock to very marked where apricots, *P. Armeniaca* are used.

4. Intervarietal incompatibility in greater or less degree has been recorded within all the species concerned.

5. Incompatibility in plums may be manifested by failure to form a union, by subsequent breaking at the union, by cessation of growth of the scion after one or two seasons, by dying back of scion, or by lack of health or premature decline of the trees after perhaps several years' apparently normal growth and cropping.

6. Work at East Malling Research Station, England, suggests that incompatibility has often been accentuated by the indiscriminate use of seedling stocks, and the employment of vegetative propagation to maintain tested clonal strains or varieties of all species of rootstocks may be expected, first, to show the true nature of stock-scion relationships, and secondly to eliminate incompatibility as a cause of losses by employing only suitable stocks for each variety.

7. Investigations in the U.S.A. also indicate that in top-working orchard trees failures have resulted from the use of scion varieties, which do not form strong unions with the particular stocks. The evidence appears to confirm the contention held at East Malling that it is often an insufficient safeguard against failure to possess a knowledge of the general behaviour of the species in combination, but that it is necessary to determine the behaviour of each scion variety with each stock strain or variety separately.

8. Reciprocal grafts in plums do not necessarily produce similar effects. Witness the fact that most European plums proved fairly successful when top-grafted onto Japanese types in California, but that trees from the reverse process usually failed.

Rootstocks for peaches

In the U.S.A. the great majority of peach trees are grown on peach seedling roots. Wickson (191) puts the proportion of trees so worked in California as nine-tenths of the total number, while Overholser and Duruz (132) more recently quote the still higher figure of 98·9% taken from a survey made in the area by Heppner. Yerkes (194) notes that in the Pacific States in general the supply of pits comes very largely from varieties used for drying such as Salwey, Lovell and Muir. In South Africa, Davis (43) also states that practically all peaches are worked on rootstocks of the same species, and Quinn (140), discussing the results of a rootstock trial, implies that a similar preference exists in South Australia, when he notes that none of the other species tested are likely to supersede the peach. None of these writers makes any mention of incompatibilities in this intervarietal combination, and it would seem that the principal reason for examining the effects of other *Prunus* species as rootstocks lies in the fact that not all soils and climatic conditions are equally well adapted to peach roots. Thus Baltet (9) in France lists seedlings of almond and plum as well as of peach as suitable rootstocks, and in England Amos and others (2) note that peaches are commonly worked on certain plums including members both of *P. domestica* and of *P. insititia*.

The peach itself is regarded by Bailey (8) as the best stock for peaches where the soil is suitable and where such troubles as root-knot are absent, although he notes that there may even be a choice among peach stocks, seedlings from southern pits being generally regarded as superior to those from northern canneries. Blake in correspondence (14) writes, however, that among a great variety of seedlings under trial in New Jersey no cases of faulty unions have been recorded, and the fact that no mention whatever of incompatibility in this connexion has been encountered elsewhere suggests that it may be regarded, at any rate for all practical purposes, as non-existent.

The apricot, *P. Armeniaca*, is used to a slight extent as a stock for peaches in California. Overholser and Duruz (132) put the proportion at about 0·8%, and state that, although there is no tendency for trees to snap at the point of union, the combination is sometimes uncongenial. Stahl (169), however, goes rather farther than this and claims that the union is often unsuccessful, and that the lack of affinity can only be remedied by double-working using a variety such as Sugar Prune as the intermediate. Baltet in France (9) also regards the grafting of peach on apricot as a difficult matter, and finally Quinn (140) and Fowler (50) describing the rootstock trial in South Australia state that peach trees of several varieties on apricot were both stunted and unfruitful.

Hard-shell and sweet almonds, *P. Amygdalus*, are occasionally used as stocks in California (191). Overholser and Duruz (132) place the percentage at 0·3, and with Chandler (22) and Hedrick (87) state that the union made is good. Baltet (9) lists the almond as a suitable stock for peaches in France. In South Australia, however, trees on almond showed marked variations in performance and were on the whole inferior to those on peach (140).

The peach-almond, " a nondescript kind of fruit midway between a peach and an almond ", comes second to peach as a stock in South Africa (43), and is also used occasionally in California (191). There seems to be little or no published information as to its performance, but a peach - almond hybrid gave very variable results and proved somewhat inferior to peach in South Australia (50, 140).

P. Davidiana, a Chinese wild peach is noted by Yerkes (194), Overholser and Duruz (132) and Stahl (169) to be more tolerant to alkali than the common forms of peach, *P. Persica*. It is considered to show promise as a stock, making good unions with peach varieties.

The Myrobalan plum, *P. cerasifera*, is very occasionally used in California as a stock for peaches (191), and was one of the seedling stocks included in the trial in South Australia where it is described by Quinn (140) and Fowler (50) as producing stunted and unfruitful trees. There was, however, one interesting exception. Of two trees of Salwey on Myrobalan the one grew very poorly, as did all those of other peach varieties, but the second tree proved as vigorous and healthy as any tree worked on peach or other stocks in the trial. Excavations proved that no scion rooting had occurred ; and suckers of this particular Myrobalan have since been taken with a view to establishing a clone by vegetative means. The variability in congeniality and

behaviour of peaches on Myrobalan seedlings is also stressed by Howard and Heppner in California (97). They tested seventy-five types and found every gradation of compatibility and incompatibilities from an apparently almost perfect stock (at four years in the orchard) to practically complete failures. They conclude that desirable types, when found, will have to be propagated asexually. The only record of a Myrobalan clone being tested as a stock for peaches comes from East Malling, England, where trials with Hale's Early on the layered selection B are described by Witt and Garner (193) and by Amos and others (2). A fair percentage of one-year-old trees was obtained in two seasons, but in both cases all of these trees had died before the end of the second year.*

Marianna, *P. cerasifera* × *P. Munsoniana*, does not appear to be used to any great extent commercially as a stock for peaches, owing probably to the tendency of trees to die back after a few years (120), although Bailey (8) mentions it as probably the best stock for light land where root-knot prohibits the use of peach stocks. It has, however, been the subject of investigations by Howard and Heppner (97) similar to those with Myrobalan described above. The results, although not so extensive, indicate that marked variability also exists in the vigour and affinity of this stock with peaches. Buds appear in all cases to unite readily with both it and Myrobalan, and shoots develop normally to a height of 4-6 feet until the beginning of August when many of them die suddenly. It appears that the roots die first from the tips upwards, but that the vessels continue to function for water transfer up to the last minute, thus explaining the suddenness of the collapse without previous symptoms. In Tennessee McClintock (118) also found that the Marianna stock died out up to the point of union when budded with Elberta peach, although in one trial this did not happen until some of the trees were three years old. Ten other varieties of peach dormant-budded on this stock exhibited sickly yellowish foliage and poor growth by the following July, and within the next two months a number of the trees died. However, when longitudinal cuts were made through some of the peach-Marianna stems the union was found to be apparently normal in every case. As with Myrobalan there appears to be only one record of the performance of a Marianna clone (2). This stock, raised from cuttings at East Malling, has, when budded with Hale's Early peach, given a consistently good percentage of two-year-old trees.

Varieties of *P. domestica* and *P. insititia* as stocks for peaches have apparently been studied only in England. Witt and Garner (193) and Amos and others (2) describe trials of Hale's Early on five clones of *P. domestica* at East Malling. Two of these, Brussels and Common Plum, have in several years always failed completely, the buds failing to unite, or the trees formed dying within two years. The three other clones, Brompton, Pershore and Kroosjespruim, have, on the other hand, given with equal regularity a good proportion of one-year-old trees in all seasons, and have shown up to five years old no subsequent mortality, which might be associated with any form of incompatibility.

Among damsons, *P. insititia*, six clones, Common Mussel, St. Juliens A and C, and the Black Damas selections B, C and D, appear to be entirely compatible with Hale's Early peach up to, at any rate, the fifth year. These results are in striking contrast to those obtained with two other St. Julien clones, D and K, and with Black Damas A, all three of which have proved total failures. In addition there are four other selections, St. Julien de Toulouse (St. Julien G), St. Julien B, the Narrow-leaved Shiny Mussel and the Broad-leaved Shiny Mussel which have given some indication of delayed incompatibility.

Prior to the work at East Malling the principal stocks for peaches in England were the Mussels, Brompton, and seedling St. Julien and Damas types. In the United States, St. Julien, again presumably raised from seed, is occasionally used as a stock, but Bailey (7) states that the union made is frequently imperfect and the trees are dwarfed. In Germany, Schindler (158) reports that the varieties Alexander and Proskau failed to unite with seedling St. Julien, and that Triumph, although giving a fair percentage of saleable grafted trees, started dying out to a serious extent when the scions had made about 1 foot of growth. There does not seem to be

* Trials with other clonal Myrobalans are, however, in progress at East Malling. These include certain selections made in California by Howard and Heppner as noted above, and a Dutch, so-called violet Myrobalan. —Ed.

any record of the performance of seedling Domestica plums in either country, although for purposes of top-working Chandler (22) considers that peach scions do not take very well either on European plum varieties or on Myrobalan, while Heppner and McCallum (91) found that they generally failed to grow on Japanese plums, *P. salicina*, as well as on European plums. On seedlings of Merunka, a Domestica plum, however, all peaches were found to give a relatively high percentage take of grafts in Germany (158).

The western sand cherry, *P. pumila* var. *Besseyi* is mentioned by Bailey (7) as used very occasionally as a stock for peaches in the United States. It apparently dwarfs the trees, but otherwise no record of its performance is given. Trials with peaches on *P. Mume* suggest that most varieties are unhealthy on this stock (166). Finally, Daniel (36) notes that he obtained fruit from grafts of peach on cherry stocks, but he does not state what growth the trees made, nor how long they lived.

Rootstocks for apricots

There seems to be a considerable divergence of opinion among authorities not only as to the best stocks for apricots, but also in certain cases as to which stocks are in most common use. Thus in California Wickson (191) notes that peach is largely used, although apricot seedlings are not uncommon, whilst Stahl (169) referring to the same region regards apricot as the chief stock with peach used only occasionally. In the United States as a whole the principal source of stocks is, according to Yerkes (194), pits from apricot varieties, and both he and Stahl claim that peach seedlings commonly fail to make good unions and are avoided for that reason. On the other hand Bailey (7) states that the apricot is not widely used as a stock for its own varieties in the United States taken as a whole with the exception of California, but that it does well on peach, which is used extensively in the warmer parts of the country. Similarly in South Africa, Davis (43) states that possibly as much as nine-tenths of the apricots there are budded on to peach seedlings, for which the best parent is a variety known as St. Helena or Transvaal Yellow, while in Victoria, Australia, apricots are usually budded on apricot seedlings (42). The position is not made any clearer by Wickson's suggestion that peach is a suitable intermediate stock to use where apricot is worked on almond.

An old paper by Bailey published in 1894 (6) may, however, throw some light on the situation, as well as being of particular interest in revealing that a congenial stock may sometimes prove to be inferior to one which shows some lack of affinity. He notes that the question of the best stock for apricots is in dispute, and goes on to describe how in Western New York State the apricot has been tried, but has been found to produce unprofitable short-lived trees. He considers that this is due, largely or entirely, to the fact that the local soils are not, in general, well adapted to the apricot root. Hence in this area the peach, common plum and Myrobalan plum have come into use as stocks for the apricot, the first named being probably the commonest, although the unions so formed are apt to be imperfect and to break during windy weather. Trees are frequently lost without any visible break at the union, but an examination under the bark will usually show that the two components have split apart internally at the union, sometimes to an extent at which the entire stem may be girdled. A similar effect has been observed with apricot on Myrobalan plum, and where such trees actually snap off at the union the fracture is commonly smooth and clean. Bailey comes to the following conclusions :—Apricot being the most congenial stock may be considered ideal on suitable soils, but, as few of these exist in western New York, the less congenial plum stocks are to be preferred for heavier land, and the equally less congenial peach stock for lighter and drier land. The plums he considers to be best top-worked and the peach nursery-budded, and in the latter case he advocates low planting so that, if possible, the unions are below ground. Finally, if the tops are also headed back to prevent undue leverage, he considers that the losses of orchard trees through brittle unions would be only very slight.

In addition to being found in New York, seedling Myrobalan appears to be used to some extent as an apricot stock in other parts of the United States (169, 194) and is also listed among several other stocks by Baltet (9) in France, where it is raised from cuttings. Hansen and

Eggers (69) in California and Davey (42) in Victoria, Australia, confirm its value on heavy soils which are apt to be wet and also the tendency of a few trees to break at the union as a result of strong winds. Bailey (7) regards it as suitable for all types of apricot whether they belong to the species Armeniaca or to Dasycarpa or Mume.

Seedling almonds have sometimes been used in California and in the south of France. Wickson (191) considers, however, that, as a general rule, this stock should be avoided. Tested extensively, it has been found that the scions do not form good unions and are easily broken off by wind. A claim that the Royal apricot will take well on seedling almond when rootgrafting is substituted for budding should not, he thinks, be accepted unreservedly to eradicate the incompatibility.

Other stocks found in use for apricots include the peach-almond and occasionally plums in South Africa. Davis (32) recommends the former together with apricot itself as stocks for use on brackish soils. Seedling St. Julien and Black Damson, both *P. insititia*, are listed by Baltet as stocks used in France, and he adds that in Holland the " Grosspflaum " (*P. domestica* ?) is employed for the same purpose. In England, Brussels, *P. domestica*, is the stock traditionally used for apricots. Budd (19) considers, however, that in Iowa St. Julien with apricot makes a weak union lacking proper vascular continuity, while Burbridge (20) in England states that on Brussels the scions begin dying off after about two years. The common plum, presumably *P. domestica*, is also stated by Bailey (7) to be in general use in the northern United States, but he adds that any of the native plums, notably Marianna, *P. cerasifera* × *P. Munsoniana*, make equally good stocks. Heppner and McCallum (91) found, however, that when Domestica and Salicina (Japanese) plums were top-worked with apricot varieties the scions generally failed. Finally Stahl (169) notes that apricots are occasionally grown in California on the Japanese or Chinese apricot, *P. Mume*, and Smith (166) describing a trial of various species on this stock refers to the growth of five apricot varieties as exceptionally vigorous at four years old and showing a smooth and apparently perfect union. Sharp plum-cot, *P. Armeniaca* var. *mandshurica*, also made a strong and smooth union, and is suggested for experimental trial as an intermediate stock for use between *P. Mume* and less congenial scions. *P. americana* makes an apparently good union with apricots in Iowa, but Budd (19) notes that its behaviour later in life has yet to be determined.

Rootstocks for almonds

Information with regard to the grafting affinities of almonds, *P. Amygdalus*, is somewhat limited, but this is probably due very largely to the fact that the two principal rootstocks, peach and almond itself, appear to be entirely compatible with commercial scion varieties. Both these stocks are used extensively in California ; in the case of the almond the bitter type being preferred to the sweet, although according to Stahl (169) and Hansen and Eggers (69) the latter would appear to be equally suitable. In South Africa, Davis (43) reports that a majority of the commercial varieties, which belong to the soft and paper-shelled group of almonds, are budded on to peach, with which they form a perfect union. He considers, however, that in brackish soils the bitter almond or the peach-almond might prove to be more satisfactory. Hard-shelled almond seedlings are also regarded as suitable stocks, and in France Baltet (9) mentions this type and plums, presumably *P. domestica*, as the only species used for almonds. Wickson (191) states, on the other hand, that, in California, plums have proved to be disappointing, while Heppner and McCallum (90) found that almond scions generally failed to grow when top-worked either on Domestica plum varieties or on Japanese plums, *P. salicina*. The Myrobalan or Cherry plum, *P. cerasifera*, has also, according to Stahl and to Hansen and Eggers, been found to make a rather unsatisfactory union. Bailey (7) claims, however, that the union is apparently strong, but that the trees are dwarfed owing to the tendency of the scions to outgrow the stock. Chandler (22) adds the trees are also short-lived. Tests with the Japanese apricot, *P. Mume*, as stock for five varieties of almond are described by Smith (166). The trees formed have not on the whole made good growth and mortality rates have in several cases been very high. The common apricot, *P. Armeniaca*, should also, in Wickson's opinion, be avoided.

P. Davidiana, the " wild peach of China ", is mentioned by Bailey (7) as a stock with which almonds unite readily, but he adds that the longevity of the trees has yet to be determined. Finally, Daniel (36) records that he grafted almond on cherry and mahaleb stems, both stocks and scions consisting of wood more than one year old, and obtained fruit from the scions, but he does not state what growth the trees made nor how long they lived.

Rootstocks for cherries

Mazzard, mahaleb and sour cherry

The cultivated cherries belong almost exclusively to two species, *Prunus Cerasus*, sour, acid, or pie cherries, and *Prunus Avium* known collectively as sweet cherries, but in the wild state by such names as Mazzard, Bird, Wild, or Gean cherries. Between these two groups comes the class known as Duke cherries which are hybrids between the two species, but are said by Hedrick (86) to show in the majority of cases more resemblance to the sour than to the sweet types. The two principal rootstocks are wild forms of *P. Avium*, known commonly as Mazzards,* and seedlings of a very different species, *P. Mahaleb*, which Hedrick describes as being botanically more distantly related to cultivated cherries than are these cherries to plums.† *P. Cerasus* is also represented to some extent by such stocks as Kentish and Stockton Morello.* Other species used occasionally as rootstocks will be mentioned at the end of this section.

Both Bailey (7) and Yerkes (194) state that mahaleb is the stock most commonly used for all types of cherries in the United States with the exception of the Pacific Coast region, where mazzard predominates. Thus we find that in California Wickson (191) puts the proportion of cherries worked on black mazzard at three-quarters of the total, while more recently Philp (134) quotes the results of a nursery survey made in 1926-7 as showing that the percentages are :— Mazzard 60·8, mahaleb 24·3, and Stockton Morello, a sour type raised vegetatively from suckers, 14·9. In England Grubb (64) records that members of all three species were found in nursery collections. In the past, however, the vast majority of both sweet and sour cherries were worked on mazzard, a few sour cherries were worked on mahaleb, but no intentional use was made of sour cherry stocks. In France Baltet (9) and in Germany Schindler (158) list the wild cherry, presumably mazzard, as the stock to use for standard trees, and state that otherwise mahaleb should be employed or the cherry grown on its own roots from seed. In South Africa, Davis (43) reports that cherries are worked on both mazzard and mahaleb, but more particularly the latter ; and finally in South Australia Quinn (138) writes that, although mahaleb has been used in the past for sweet cherries, in recent years it has been entirely superseded in popular favour by mazzard.

In view of the fact that two different species of *Prunus* are represented among scion varieties and three in rootstocks, and that one stock in particular, mahaleb, is botanically not very closely related to any scion varieties, it is of interest to record that in only one instance among commercial fruiting cherries has a definite assertion of complete incompatibility been found in the literature. This concerns a sweet cherry, Chapman, on the sour cherry Stockton Morello, which has to be double-worked, and which Philp (134) claims is the only combination on this stock among Californian varieties which has been found to show lack of affinity. There does, however, seem to be a possibility that a mild and much delayed form of incompatibility may occur in other combinations and Quinn (138) in South Australia describing a rootstock trial expresses an opinion that the five sweet cherry varieties under investigation showed some lack of compatibility with both mahaleb and a sour stock.

The influence of all three stocks appears to be very similar whether the scion variety is a sweet, a sour or a Duke cherry, and the descriptions given by the various authorities show with few exceptions close agreement. Bailey (8), who regards mahaleb as inferior to mazzard,

* Throughout this section *P. Avium* stocks will be referred to as mazzards and *P. Cerasus* stocks as sour stocks.

† *P. Mahaleb* belongs to section *Padus* of genus *Prunus*, as do *P. demissa*, *P. Padus* and *P. serotina* which are mentioned among the stocks occasionally used or are to be found listed in Table 6.

states, however, that sour cherries are more likely to prove unsatisfactory on this stock than sweet, whereas Chandler (22) observes that sour cherry trees on mahaleb seem to be more uniformly good than comparable trees on mazzard. Mazzard in the nursery is not so easy to bud as mahaleb for several reasons, none of which, however, appears to be associated with any incompatibility. In early growth, trees on mahaleb are also more vigorous and uniform, but under suitable conditions trees on mazzard ultimately produce a large long-lived tree, and throughout their life give no indication of any delayed form of incompatibility. The comparative behaviour of sweet cherry stocks and mahaleb has been clearly shown in a number of rootstock trials, the results of which are described below.

Howe (98, 99, 100) describes a trial in New York State in which two trees each of seventeen varieties of sweet cherry, fourteen of sour, and nine of Duke were worked on both mahaleb and mazzard seedlings. The behaviour of the trees was compared at seven and again at fourteen years. A considerable proportion of the trees on mahaleb were found to have died within the first seven years, and by fourteen years this proportion had risen to over 50% in each group of scion varieties, and many of the remaining trees were weak or actually moribund. By contrast, only four trees on mazzard had died during the same period and the remainder were, with very few exceptions, vigorous and healthy.

The opinion expressed by Quinn (138) that sweet cherries may show some lack of compatibility with mahaleb and sour cherry stocks has already been noted. The trial, upon the results of which this opinion was based, was carried out in South Australia, using five sweet cherry varieties budded on to mazzard, mahaleb, Kentish or Morello sour stock raised vegetatively, and on to a Kentish intermediate stem piece superimposed on mazzard. Records were taken over a period of twenty-four years. The trees on mahaleb grew vigorously at first, but ultimately growth became weaker and by the end of the trial six out of fifteen trees had died and the remainder were showing more or less evidence of progressive dying back at the terminals. As a result of root excavations it was discovered that some of the main roots of these trees had died, and had not subsequently been replaced. It is pointed out, however, that some of the trees which died were among the largest in the orchard. The trees of sweet cherry on mazzard showed no sign of incompatibility, being a good size, and cropping better than those on either of the other stocks over the twenty-four year period. Dead roots were again revealed by excavations, but in this case they had been replaced by new ones. The double-worked trees with the sour cherry intermediate on mazzard were also a good size and showed no apparent incompatibility, and the only effect of the inter-stock seemed to be a reduction in cropping as compared with the trees worked direct on mazzard. With the third rootstock, Kentish, there was no dying back of roots or terminals, and at twenty-four years they were still healthy. Unlike the trees on mahaleb, however, they were dwarfed, and the assertion that they showed some lack of compatibility appears to be based on this character. Quinn tenders the conclusion that these results confirm the views of local growers who in recent years have abandoned all other stocks in favour of mazzard for sweet cherries.

An investigation into the behaviour of clonal selections of sweet cherry, sour cherry and mahaleb rootstocks has been in progress at East Malling Research Station, England, since 1913. Grubb (64) describing their effects with particular reference to the sour cherry variety, Morello, notes that the mazzard selections were found to produce measurable differences in the scions as regards vigour of growth, weight of crop and character of the fruit and adds that there are indications that the mahaleb and sour cherry selections will produce similar differences. No suggestion is made, however, that there were any differences in compatibility between the scion variety and the various rootstock strains, and apart from the variations found to occur within the species the general behaviour of the stocks of each species collectively appears to have been somewhat similar to that recorded in South Australia by Quinn for sweet cherry scions. The trees on mahaleb were the most vigorous in the nursery and at first in the plantation, but by the fifth or sixth year the growth rate had begun to decline, and the trees became weaker and more spreading. Grubb is of the opinion that they will probably be shorter-lived than the trees on mazzard. The trees on sour cherry were much dwarfed, and their crops were light, although in some cases fair in proportion to tree size. The most recent account of the same

trials is supplied by Amos and others (2) in 1936. They state that among all the clones selected at East Malling no definite case of incompatibility has occurred with any sweet or sour cherry worked upon them. The only combination which may possibly be uncongenial is Morello on certain mahaleb selections. The trees cropped heavily for several years, but then lost their early vigour, and by the time they were nine to ten years old three out of the eighteen trees originally planted had died.

Several other authorities refer to mahaleb as a dwarfing stock producing a relatively short-lived tree, although Hedrick (86) emphasizes again that this diminution in size may not become apparent during the first few years and even during the first decade, whilst Philp (134) reports having seen a few exceptions to this rule in California, trees fifty years of age and showing no dwarfing effect. Bailey (7) suggests, however, that it is to be expected that trees on mahaleb would be smaller than trees on mazzard, because the mahaleb stock by itself is naturally a smaller tree. Both Fowler (50) in South Australia and Philp in California also note that the scion tends to overgrow the mahaleb rootstock and that there is a marked constriction at the graft union, although Philp adds that this effect may apparently be largely obviated by low planting. Hedrick merely states that unions formed between scions and mazzard are better than those formed with mahaleb, but Budd (19) as long ago as 1890 stressed the inferiority of the union with mahaleb as being responsible for the unhealthy growth and relatively high mortality of two- and three-year-old trees of many varieties in Iowa. He found the varieties affected to be mainly those with coloured as opposed to pale juice, and considered their failure to be due largely to winter injury, which in turn was attributed to lack of continuity at the union preventing proper transfer of elaborated foods to the roots. As a point of interest it may be added that the reciprocal graft of mahaleb on any cultivated cherry, according to Hedrick (82) and Sahut (155), invariably fails, although again it may be noted that Cummings and others (35) claim to have made some successful grafts of mahaleb on mazzard in Vermont.

From a commercial standpoint the position with regard to a choice between mazzard and mahaleb appears to be well summed up by an anonymous writer in Canada (3). He states that for both sweet and sour cherries mahaleb is the better nurseryman's stock, being more easily budded and producing saleable trees more quickly, but that in the plantation mazzard ultimately makes the larger, thriftier, longer-lived and more productive tree.

There seems to be very general agreement that sour cherries by comparison with mazzard make stocks distinctly dwarfing in their effect upon all scion varieties, although Lindemuth in an old paper (117) makes the somewhat enigmatical statement that sour cherries do not do so well grafted on to sweet cherries as do sweet on sour. Of the Stockton Morello, a type raised from suckers, Philp (134) says that it is a dwarfing stock with which the scion shows a very great overgrowth above the union, but in which the union itself appears to be strong and shows no breakage. The only variety regarded as incompatible with it is the sweet cherry, Chapman, as was noted earlier, although Hansen and Eggers (69), while considering it to be a commercially satisfactory stock, claim that there are several varieties with which it does not make good unions. In Illinois, Blair (13) writes that the union of sour cherries with Stockton Morello seems to be satisfactory and that the overgrowth, though rather greater than with similar trees on mahaleb, is even then not very pronounced. The Kentish or Morello is likewise raised from suckers or chance stools in South Australia where it is also described by Fowler (50) as a dwarfing stock, but in this case it appears to be the stock section of the stem which produces the overgrowth.

Other rootstocks occasionally used for cherries

The small wild red, Bird, Pin or Pigeon cherry, *P. pennsylvanica*, is mentioned by Hedrick (86) as a hardy stock tending to dwarf standard varieties, and he quotes Macoun as stating that it is commonly used in the colder regions of Canada with good results. A report to the same effect has been made more recently in connexion with some trees growing on this stock at the Central Experimental Farm, Ottawa (3). Bailey (7) also notes that *P. pennsylvanica* unites readily with both sweet and sour cherries, but adds that, although healthy and vigorous specimens sixteen to eighteen years old are to be found, it has yet to be determined how long the trees as

a whole will live. Trees of Early Richmond, a sour, and Windsor, a sweet cherry, showing no signs of incompatibility up to six years old are reported by Cummings and others (35).

The Sand cherry, *P. pumila*, is used successfully as a stock for sour cherries in the colder parts of America, and Budd (19) wrote in 1890 that, although its use as a stock was somewhat experimental, it had been proven to unite well and to make a tree no more dwarfed than one on mahaleb during the first five years of growth. Bailey considers that *P. pumila* and another Sand cherry, *P. pumila* var. *Besseyi* both show promise as dwarfing stocks, but Hansen (70) states that cherries will unite with the latter only with difficulty, whether budded or grafted.

Hedrick quotes Lewelling (116) as stating that the Choke cherry, *P. virginiana*, was used as a stock in Oregon in 1850 when no other species was available, and that the union formed was very good. He doubts, however, whether the use of a stock so distantly related to cultivated forms would be very desirable, and Cummings and others (35) found this species to make a poor union with Early Richmond, a sour cherry, and Windsor, a sweet cherry, in Vermont, while in New York State it has proved uncongenial with Montmorency, another sour variety (176, 177).

The Rum or wild Black cherry, *P. serotina*, is also reported as having been used as a rootstock, but, as it belongs to the same section of *Prunus* as *P. virginiana*, Hedrick expresses a similar doubt as to its suitability. This is borne out to some extent by Cummings and others (35) in Vermont who found that it made poor unions with Windsor and Early Richmond, a sweet and a sour cherry respectively.

Hedrick quotes a reply from Japan in which it is stated that, in addition to the common types of stocks, a vegetatively raised horticultural variety of *P. Pseudo-cerasus*, known as Dai-Sakura, is used in the northern part of the main island as a stock for European cherries. It has a rather dwarfing influence and induces early bearing, but no mention is made of the closeness or otherwise of its affinity with scion varieties.

Three selections of *P. tomentosa*, a very dwarf species used in China as a stock for the Chinese early cherry, *P. Pseudo-cerasus*, were tried as stocks for Morello at East Malling, but according to Amos and others (2) all the plants failed to make any growth. Similarly in New York State seedlings of this species are reported by Tukey and Brase (177) to be uncongenial with the sour cherry Montmorency.

P. serrulata, a Japanese flowering cherry, is mentioned by Cummings and others (35) as showing no signs of incompatibility with Early Richmond, a sour, and Windsor, a sweet cherry, up to the time the trees were six years old, although some dwarfing was evident.

The peach, *P. Persica* is, according to Davis (43) entirely unsuitable as a stock for cherries. When budded a union may be formed and a shoot develop for perhaps a year, but the combination invariably dies an untimely death.

Among other species represented by scion varieties mention is made by Baltet (9) of *P. Padus*, the true Bird cherry. The only stock suggested for it in France is seedlings of the same species. A layered selection of this species has also been tested as a stock for Morello on two occasions at East Malling, but Amos and others (2) state that the combination proved completely incompatible.

Marked incompatibility has been shown at East Malling by six varieties of ornamental cherries budded on five mahaleb clonal selections (2). Whereas similar trees on the mazzard selections all grew vigorously, in four varieties on mahaleb failure was complete, in one the buds started growing but failed to make one-year-old trees, and in the remaining variety one-year-old trees were obtained but all died by the end of the second season.

CONCLUSIONS AND SUGGESTIONS

A study of the literature on stock and scion relationships indicates that the phenomena we call stock influence, scion influence and incompatibility arise from the physiological and structural differences that must exist between all plants of different species and varieties. Very few of these differences have been determined quantitatively, and the nature of the reactions which they produce are for the most part obscure. Nevertheless, attempts have been made from time to time to give general descriptions of these internal reactions based on observations of the behaviour of grafted plants in the field. Perold (133), for instance, refers to functional differences between grape vine stocks and scions and explains how these differences affect the growth and longevity of grafted vines. He uses the symbols Ca and Cv originated by Daniel (37) to represent what that writer called the " functional capacity of absorption " and the " functional capacity of consumption ". The first of these refers to the capacity of the root system to absorb nutrients from the soil and the second the capacity of the aerial parts of the plant to transpire water, assimilate carbon dioxide and elaborate and consume food. It is suggested that, provided conditions are not abnormal, Ca and Cv in the ungrafted plant will be in a state of equilibrium during the period of active growth, a relation which is expressed by the formula $Cv = Ca$. On the other hand, in the grafted plant, where stock and scion are of different varieties and the functional capacities have to be expressed as Ca and C^1v, both Perold and Daniel consider that the relation $C^1v = Ca$ never occurs, and the former writes that " in grafting practice we have, therefore, always to do with an unequal relation between stock and scion ". In the case of grape vines, rootstocks are normally selected with the object of forming large, vigorous plants and hence the relation commonly found is $C^1v<Ca$. As the plant grows older, however, he considers that the root system tends to become relatively weaker and the functional relation between stock and scion gradually passes from $C^1v<Ca$ through $C^1v = Ca$ to $C^1v>Ca$. In addition, the union, by obstructing the upward and downward flow of sap to a greater or less extent, is held to reduce the discrepancy between Ca and C^1v when $C^1v<Ca$ and to accentuate it when $C^1v>Ca$. The span of life of the grafted plant is shorter than that of the ungrafted vine which spends the greater part of its existence in or near the condition $Cv = Ca$. The life of the grafted vine is reduced, the more $C^1v<Ca$ or $C^1v>Ca$.

Now it seems very doubtful in the light of much available evidence whether the relations between stock and scion can be accurately expressed in such a simple manner. In the first place Daniel and Perold appear to make no allowance for the fact that the stock or scion may alter the so-called functional nature of the other component. Not only is this made clear from differences in growth and fruiting habits of a single variety grown on different rootstocks, but it has also been shown conclusively that a stock may increase or decrease the amount of certain substances normally present in the scion, while the scion may exert a similar effect upon the stock. Reference to the functional capacities of ungrafted plants will not, therefore, necessarily provide a reliable indication of their functional capacities when grafted. Secondly, it cannot be concluded that in all ungrafted plants an organically ideal state of equilibrium will exist between the functional processes of the root system and aerial parts under all conditions of soil and environment. By using rootstocks of a different species from that of the scion it is possible, for example, to grow fruit trees under alkaline soil or low temperature conditions where the trees on their own roots would fail completely. Moreover, the fact that certain apple stock and scion varieties grow more vigorously when grafted than either variety does when grown alone suggests that there are factors other than those of environment which may restrict the functional capacities either of absorption or of consumption in an ungrafted plant. Thirdly, as might be anticipated from the above remarks, there does not appear to be any evidence to show that all, or even the majority of grafted plants will be shorter lived than their stocks and scions grown alone, provided that the plants concerned are " compatible ". Finally there seem to be no data which

indicate that a good union between stock and scion causes any obstruction whatever to the passage of nutrients up or down the stem.

Nevertheless, in so far as physiological and structural differences must exist between different species and varieties, the general principle laid down by Perold, that in grafting practice we are always concerned with an inequality between stock and scion, must be accepted. The nature and extent of the reactions which occur as a result of these differences will depend primarily upon the combination concerned and its particular stage of growth, but will also doubtless vary to a considerable extent with different environmental conditions. The various reactions, through their influence on physiological processes in the grafted plant, may clearly be either beneficial or detrimental to its development. Among the calculable effects of " beneficial " reactions are found such characteristics as improved vigour, improved fruiting and fruit quality, greater resistance to cold and disease, and greater tolerance to certain unfavourable soil conditions. These characteristics we attribute mainly to " stock influence ". Among the calculable effects of " detrimental " reactions are found such characteristics as failure to form a union, premature death, unthriftiness and reduced resistance to disease. These characteristics we again associate either with stock or scion influence, or with incompatibility between stock and scion.

In considering the factors determining the " build-up " of a fruit tree, Tukey and Brase (178) note that the rootstock may be the limiting factor in one case, the union in another and the scion in yet another. The separation of characteristics into those due to stock influence and those due to incompatibility must at best be arbitrary since our present knowledge only permits us to attribute both phenomena to reactions between stock and scion which cannot be distinguished in the two cases. The expression " stock influence " is generally employed when the stock appears to transmit its own characteristics to the scion. Thus, if a stock of a dwarfing type produces a dwarf tree when grafted with a more vigorous variety, or if a stock naturally susceptible to a disorder such as leaf scorch increases the susceptibility of the scion variety to the disorder, the alteration of the scion's characteristics would commonly be attributed to stock influence. On the other hand, the term " incompatibility " may in its broadest sense be employed wherever a combination of plants produces unsatisfactory characteristics which are not found in either stock or scion grown alone. Thus, if a vigorous and disease-resistant stock grafted with a vigorous and disease-resistant scion variety produces a dwarf or disease-susceptible tree, the effect may be attributed to a discordant or antagonistic relationship between stock and scion, that is, to incompatibility. These examples have been given to illustrate how difficult it may sometimes be to distinguish between the manifestations of stock influence and lack of compatibility. The two phenomena merge one into the other, but it is clear that, if the term " incompatibility " is to serve any useful purpose in describing the performance of certain graft combinations, a line must be drawn somewhere between it and stock influence. This in fact is done in practice, but unfortunately there appears to be no general agreement as to what characteristics should be regarded as symptomatic of incompatibility, and, hence, combinations classed as incompatible by one authority may, on exactly the same characters, be classed as compatible by another authority. It is for this reason that the relationships between different so-called manifestations of incompatibility and the performances of grafted trees have been discussed in some detail in this paper.

From a practical point of view graft combinations of deciduous fruit trees may be divided into three main groups :—

1. Combinations in which the physiological and structural differences between stock and scion are so slight or of such a nature that all or the majority of grafts unite successfully and grow satisfactorily. It is possible, of course, that under certain conditions some of these trees may exhibit slight dwarfing or some abnormality such as union overgrowths which suggest a discordant association between stock and scion, but in so far as they grow and crop in an otherwise normal manner it would seem advisable, from the pomological point of view, to consider them compatible.

2. At the other extreme are found combinations in which the differences between stock and scion are such as to render satisfactory union impossible, and there is failure in all individuals,

although this failure may be delayed for a time. Cases in which it is impossible to obtain any union are commonly referred to as " completely incompatible ". Cases in which failure at the union is general, but only shows itself after one to a number of years, are also sometimes referred to as showing complete incompatibility, or may be said to show " delayed incompatibility ". Provided that the behaviour of the trees is fully described it would not appear to matter which of these expressions is used, although in the interests of accuracy " delayed incompatibility " should be changed to " delayed symptoms of incompatibility ", since it is not the incompatibility itself which is delayed but its outward and visible manifestations.

3. Intermediate between these two groups are combinations in which the differences between stock and scion are apparently less or are of such a nature that failure is shown by some pairs and not others, or the degree of failure varies sufficiently with individuals or with environmental conditions to allow of success in a larger or smaller number of cases. Included in this group are cases sometimes referred to as compatible and at other times as slightly or partially incompatible or showing some lack of affinity. It is here that difficulties arise in deciding which combinations should or should not be called incompatible. They arise mainly, as has already been noted, from the lack of general agreement on what growth characteristics constitute symptoms of incompatibility, but, before any attempt can be made to discuss this question, it is first necessary to appreciate the part played by environment in accentuating or mitigating the symptoms of incompatibility.

Opinions on the subject of environmental conditions as related to incompatibility appear to fall into two fairly well defined groups. In the first place there are authorities who, while acknowledging that incompatibility may sometimes be due solely to differences between stock and scion, also consider that adverse environmental conditions may induce incompatibility in certain graft combinations, which, under other conditions, will be compatible. They would call any scion variety incompatible with a stock which shows any type of failure or abnormality under conditions where the same scion variety succeeds on other stocks. Secondly, there are others who would apply the term only to special classes of failure, which they always relate to some inherent characteristic of the two plants. Different conditions of environment and treatment cannot, in their opinion, induce incompatibility, but may accentuate or mitigate, and hasten or retard the appearance of symptoms of incompatibility. Hence they regard certain forms of failure, which may sometimes be produced solely through the agency of adverse environmental conditions or treatment and at other times through the existence of incompatibility, as unreliable indications of the degree of affinity between stocks and scions.

In the first case, therefore, any combination of stock and scion which fails in any respect by comparison with the same scion variety grown on another rootstock may be called incompatible even if that failure occurs only under particular conditions of treatment and environment and in a trial made in only one season. When the term is used in this sense the " degree " of incompatibility can be correlated with such so-called symptoms as the number of successful unions formed and the prominence of union overgrowths. In other words a combination which in any one trial gives only a 25% " take " of buds or grafts may be considered to show a greater degree of incompatibility than another which gives a 40% " take ", and similarly a tree with a large union overgrowth may be regarded as showing more incompatibility between stock and scion than one with a small union overgrowth. To justify making such comparisons it is necessary to hold that the appearance of incompatibility is governed to a large extent by local conditions of treatment and environment and that any unsuitability of stock and scion *inherent* in the species plays a comparatively small part. This opinion receives some support from such examples as the reported congeniality of the pear variety Duchesse d'Angoulême with quince in the United States and England and its failure on this type of stock in Germany, and the successful use of mahaleb as a stock for sweet cherries in some districts and its failure for this purpose in others. Perhaps the best example, however, is the widespread use of the sour orange as stock for citrus varieties in many parts of the world and its almost complete failure with all types of citrus in South Africa and Java. Moreover, the fact that climate, age of material and method of propagation have pronounced effects on the stand of trees produced and in some cases on their subsequent development, and that low budding may eliminate union overgrowths in

certain combinations which show prominent overgrowths when top-worked, must be considered to lend weight to this opinion.

On the other hand the majority of the data available indicate that in most cases particular local conditions of soil and climate offer insufficient explanation of the unsatisfactory behaviour of many grafted plants, and that, in practice, most combinations reported in one place to be unsuccessful exhibit comparative failure wherever they may be grown. If this is true, incompatibility may be regarded as an inherent antagonism or discordant association between certain stocks and scions, the cause or causes of failure or abnormalities arising out of the nature of the two plants, and the form taken by the failure being governed in greater or less degree by the subsidiary factors of environment and treatment. Thus, under external conditions which favour union and growth failure will tend to be delayed, while under unfavourable conditions of environment and treatment it will tend to be accelerated.

The so-called symptoms of incompatibility may for convenience be divided into three groups. In the first place there are those symptoms, associated with tree failure, which appear to arise solely as a result of the inherent differences between stock and scion. The breaking of stems at the union and the premature death of trees attributed to the formation of parenchymatous or corky layers at the line of union appear to be symptoms of this type. Secondly, there are other symptoms also associated with comparative or complete failure which may arise either from the inherent differences between stock and scion or from environmental conditions or from a combination of these factors. They include failure to form a union, stunting and ill-health of trees, which may be due to adverse conditions of soil, climate and treatment as well as to incompatibility between stock and scion. Thirdly, there are symptoms which, like the last, may arise from inherent differences between stock and scion or from external conditions, but do not appear necessarily to denote tree failure. These include union overgrowths which may be due apparently to a reaction produced by faulty manipulation of grafts as well as to reactions resulting from differences between stock and scion.

The fact that several factors may produce the manifestations noted above appears to be responsible for the confusion which has arisen regarding the use of the term incompatibility. The question, to which an answer is desirable, is whether the term may most profitably be used to describe a certain set of symptoms regardless of the nature of the factors producing them, or whether its use should be restricted only to such symptoms as can in any particular instance be attributed to the inherent differences between stock and scion. The answer must clearly depend upon whether it is environmental conditions or the differences between stock and scion which are, in general, the more responsible for the appearance of these symptoms. Evidence supporting the view that environment and treatment rather than the nature of stock and scion are primarily responsible for failure in grafted trees has been presented, but it may be noted here that the most conclusive evidence on this point has been obtained, not with deciduous fruit trees, but with citrus species, in which, as recent work has suggested (173), the problem of incompatibility may be of a somewhat different nature. It is also true that certain of the types of failure, such as ill-health or failure to form a union, may possibly be due more often to adverse conditions of environment and treatment than to differences between stock and scion, but the fact remains that there are certain other forms of failure which can only be attributed to physiological and structural differences between the two plants, and this, taken in conjunction with the fact that deciduous fruit trees showing these forms of failure in one place generally show comparative failure in other places, would make it appear desirable to restrict the use of the term incompatibility to such cases of failure as can clearly be attributed to the reaction between stock and scion.

Arising from this discussion, therefore, it is suggested that for practical purposes :—

1. The term incompatibility should be applied only to such combinations as show distinct failure (i.e. failure to unite, failure to grow in a healthy manner, or premature death), and only where such failure can be attributed with a reasonable degree of certainty to differences between stock and scion.

2. The term incompatibility should not be applied to cases in which conditions of treatment and environment would appear to be the most likely cause of failure, or to cases where abnormalities (e.g. union overgrowths), not accompanied by tree failure, occur.

3. For each individual combination the form of failure or the characteristics of any abnormality should be stated clearly. In the past adequate descriptions of unsatisfactory tree performances have been the exception rather than the rule.

The symptoms of inherent incompatibility

The following conditions are apparently symptomatic of incompatibility and of no other disordered state, and may thus be regarded as reliable indications :—

1. The presence of isolated masses or sheets of parenchymatous or bark tissue at the line of union in place of normal, differentiated tissues.
2. The breaking off of trees at the point of union, particularly when they have been growing for some years in the orchard and when the break is clean and smooth.

It is suggested that the following conditions are symptomatic of incompatibility only if they occur on a large scale in trees grown under various conditions of environment and treatment :—

1. Complete failure to form a union. This result obtained in one season or with only one method of propagation is not necessarily a reliable indication of the effects which would be produced in other seasons or by other methods of propagation.
2. Premature decline and death of the trees.
3. Ill-health in trees.

The following conditions may conceivably be symptomatic of incompatibility in certain combinations of plants, but must in general be regarded as untrustworthy indications, in that they may sometimes be manifested in otherwise normal and satisfactory trees.

1. A relatively low proportion of unions formed.
2. Differences in growth rates or vigour of stock and scion, either before or after grafting.
3. Differences between stock and scion in times of commencing or terminating growth.
4. Swellings at the union.

It is suggested that where any of these four conditions is observed no conclusion as to the existence of incompatibility should be drawn, but the condition itself should merely be described.

The causes of inherent incompatibility

Attempts to associate incompatibility with physiological or biochemical differences between stock and scion or with the occurrence of normal or acquired precipitive reactions between the proteins of stock and scion have so far given inconclusive results.

Incompatibility in deciduous fruit trees

The account given in the third section of this paper indicates that in both pome and stone fruits incompatibility may sometimes be demonstrated, not only between different genera and species, but also between different varieties of the same species. This shows that incompatibility bears no exact relationship with botanical affinity, and also helps to explain why the use of seedling rootstocks is in some cases attended by marked variations in success.

PRELIMINARY SUGGESTIONS FOR A RESEARCH PROGRAMME ON STOCK-SCION INCOMPATIBILITY

The problems connected with the graft-affinities of stocks and scions can doubtless be approached from a great many different directions, and no one programme of investigations is likely to include studies upon all aspects requiring elucidation. Hence, the purpose of presenting here a tentative programme is twofold :—First to provide workers in different parts of the world with suggestions as to possible lines of approach ; and secondly, and perhaps this is the more important, to invite criticisms and further suggestions from these workers. In the lists that follow consideration has been given to those problems that have already been studied to some extent but have not been sufficiently clarified, and also to certain other aspects which do not, up to the present time, appear to have received any attention. With reference to the latter group of suggestions, however, it may be noted here that those marked with a bold asterisk (∗) have been the subject of investigation by Dr. W. T. Chang of the National University of Chekiang, Hangchow, China, at East Malling Research Station during the past two years. The results obtained, many of which would appear to be of considerable significance, will probably be published in a forthcoming number of the *Journal of Pomology and Horticultural Science*.*

(1) A STUDY OF THE FACTORS GOVERNING THE SUCCESS OR FAILURE OF BUDS AND GRAFTS TO FORM A UNION

(i) The effect of different methods of propagation such as budding, whip-grafting, wedge-grafting and inarching on subjects which have failed to form a union when worked in one or another common method.

(ii) The effect of time of grafting or budding, to be determined by working series of trees at intervals of, say, a week.

(iii)∗ The effect of climate with particular reference to rainfall, temperature and atmospheric humidity.

(iv) The effect of soil moisture, to be determined under a range of controlled conditions of temperature, humidity and water supply.

(v) The effect of the nutrient status of stocks and scions. The stocks might be subject to different manurial treatments and the scions taken from manurial plots, and also perhaps from trees suffering from deficiency diseases.

(vi) The effect of the position of the buds on the budwood and the use of budwoods of different types, such as leader shoots, weak laterals, etc.

(vii) The effect of the position of the top bud of a graft in relation to the tongue of the graft. The effects found in connexion with apples might be examined for other fruits.

(viii) The effect of age and size of stock and scion in connexion with both nursery grafting and top-working.

(ix) The effect of the age of stock trees in relation to the use of their roots for bench-grafting.

(x) The effect of different tying and waxing methods, with particular reference to the effect of pressure and to the exclusion of air from, and the maintenance of high humidity at, the union.

* Thesis entitled " Studies in incompatibility between stock and scion with special reference to certain deciduous fruits," presented in part fulfilment of the requirements for the degree of Doctor of Philosophy in Horticulture in the University of London, 1937.

(2) Studies of the growth of trees on different rootstocks

(i)* A comparative study of the growth cycles, including growth rates and characteristics, of different stock-scion combinations and of unworked stocks from the stage of bud break to that of maiden tree.

(ii)* A comparison of the root development of different worked and unworked rootstocks, known to be compatible or incompatible with certain scions ; and a comparison of the shoot : root ratios of compatible and incompatible trees.

(iii) Experiments to determine what factors are responsible for delaying or hastening the appearance of symptoms of incompatibility in combinations in which tree failure is normally delayed for several years. These might include a study of the effects of manurial treatments, the nutrient status of trees, drought, soil conditions, low temperature, etc.

(3) Tests to determine the mechanical strength of unions

(i)* Breaking tests made at, above and below compatible and incompatible unions of different ages and produced by various methods of budding and grafting.

(4) Studies of the anatomical structure of unions

(i)* A study of callus formation in various combinations to determine what relationships exist between the amount of callus produced, the formation of the union, and the environmental factors denoted in (1).

(ii) A similar study to determine the relationship between the rate of callus formation and subsequent cell differentiation upon the nature of the ultimate union.

(iii)* A study of the uniting of tissues in grafts, using a purple-tissued type, such as some varieties of *Prunus cerasifera*, as one of the components of the graft.

(iv) An examination of unions at regular intervals from the time of budding onwards to determine what differences, if any, exist between compatible and incompatible unions, and to correlate these differences with external manifestations or symptoms of incompatibility. This to be done on as wide a range of subjects as possible and with reciprocal grafts in each case.

(v) A comparison of the two unions formed in double-worked trees.

(5) Studies of translocation in grafted trees

(i) A study of the orientation of stock and scion tissues formed after grafting by means of dyes to determine whether the scion influences orientation of the stock tissues to a similar extent in different species, and in compatible and incompatible combinations.

(ii)* Studies to determine the water contents and water conductivity of different stocks and scions both when grafted and unworked, and to determine the permeability of the graft union to substances injected either above or below the union.

(iii) Studies to determine the effect of different unions upon the movement of foodstuffs in the phloem. These might include tests for starch accumulation above and below the union*, and an examination of the effects of ringing grafted trees and of grafting bark rings of a partially incompatible species around the stems of trees.

(6) Physiological and biochemical studies

(i)* Attempts to restore the vigour and health of trees showing signs of incompatibility by injecting nutrient materials either above or below the union.

(ii) Estimations of the carbohydrate : nitrogen ratios of trees on different stocks.

(iii) Chemical analyses to determine the influence of compatible and incompatible stocks upon the contents and proportions of various substances in the scion, and similarly the effect of the scion upon different rootstocks, the comparisons being made between grafted and unworked trees.

(iv)* A study of the relative susceptibility of compatible and incompatible combinations to diseases, and in particular to physiological disorders.

(v) A study of growth promoting substances in relation to grafted plants.

ACKNOWLEDGEMENTS

The writer is greatly indebted to Professor V. H. Blackman, Director of the Research Institute in Plant Physiology, Imperial College of Science and Technology, London, not only for contributing a foreword to this paper, but for his invaluable assistance in reading through the manuscript and making many helpful suggestions.

The paper has also been read by Dr. R. G. Hatton, Director of East Malling Research Station and of the Imperial Bureau of Fruit Production ; Mr. D. Akenhead, Deputy Director of the Bureau ; and Dr. W. T. Chang, Pomologist at the National University of Chekiang, Hangchow, China, to each of whom thanks are due for valuable criticism.

Finally the writer gratefully acknowledges the time and trouble taken by the following research workers in replying to queries :—

Mr. W. H. Alderman, Department of Agriculture, Minnesota.

Professor R. D. Anthony, School of Agriculture and Experiment Station, The Pennsylvania State College.

Dr. L. P. Batjer, Agricultural Experiment Station, West Virginia.

Professor J. C. Blair, Illinois Agricultural Experiment Station.

Professor M. A. Blake, State of New Jersey Agricultural Experiment Station.

Mr. L. H. Day, University of California.

Mr. B. D. Drain, The University of Tennessee, Agricultural Experiment Station.

Mr. A. C. Gossard, United States Department of Agriculture, Bureau of Plant Industry.

Mr. T. J. Maney, Iowa State College of Agriculture and Mechanic Arts.

Professor R. H. Roberts, University of Wisconsin, College of Agriculture.

Mr. A. Lee Schrader, University of Maryland, Agricultural Experiment Station and College of Agriculture.

Professor J. K. Shaw, Massachusetts State College.

Mr. H. B. Tukey, New York State Agricultural Experiment Station.

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APPENDIX

Note on Tables 1 to 6

Rootstocks which have been used, either experimentally or commercially, for varieties of pears, plums, peaches, apricots, almonds and cherries are listed in Tables 1, 2, 3, 4, 5 and 6 respectively, together with notes on the behaviour of each combination. No table is provided for apples owing to the relatively few cases of incompatibility reported. The lists are arranged in alphabetical order according to the botanical names of the rootstocks, and under each of these the botanical and varietal names of the scions are similarly placed in alphabetical order. For purposes of uniformity the generic and specific names used have been taken, wherever possible, from the " Hand-list of trees and shrubs, grown in the Royal Botanic Gardens, Kew ",* which is based on the now generally accepted international rules of nomenclature. In order to assign horticultural varieties to different species, in cases where the authors concerned have not themselves done so, use has also been made of the classifications prepared by Hedrick and others (85, 86, 87, 88). It is almost inevitable, however, that some mistakes in nomenclature have been made in the lists, especially among the less common and the newer types which have not yet been carefully classified. Moreover, the lists cannot be regarded as by any means a complete record of all combinations tested, nor as an infallible guide to the behaviour of all such combinations as are listed. Among descriptions of behaviour that have been found in the literature such qualifications as " makes unsatisfactory trees " and " gave a low percentage ' take ' of buds in one year " must often, for lack of corroborative evidence, be regarded with extreme caution. It seems highly probable, however, that some of this evidence may already be in existence, but has been omitted from these lists, either because it has appeared in papers not available to the writer, or because it has not so far been published. The Bureau would, therefore, welcome any information regarding further literature on the subject or any individual amendments or additions which might be made to the present lists.

* Published in several sections at different dates by H.M.S.O., Aldwych, London.

TABLE 1

ROOTSTOCKS TESTED FOR PEARS, *PYRUS COMMUNIS* AND HYBRIDS

No.	Stock.			Scion.		Behaviour.	Where observed.	Cited from.
	Species.	Variety.	How propagated.	Species.	Variety.			
1	*Amelanchier canadensis*	June-berry or Service-berry	—	*P. communis*	Pears in general	Buds unite, but union is very poor and trees always break off after a few years.	Iowa, U.S.A.	122
2	*Crataegus* sp. ?	Thorn	seedling	,,	,,	Good dwarf trees are often reported.	U.S.A.	7
3	*C. Oxyacantha*	Hawthorn (Whitethorn)	,,	,,	,,	Sometimes used as a stock, details lacking.	France	9
4	,,	,,	—	,,	,,	Unite readily.	U.S.A.	82
5	,,	,,	seedling	,,	,,	Results little better than pear on apple.	England	20
6	,,	,,	,,	,,	Fertility	Trees at 9 years very vigorous.	East Malling, England	2
7	,,	,, 3 selections	layered (clonal)	,,	Reine des Poires	Completely incompatible, no 1-year-old trees produced.	,,	2
8	*Cydonia vulgaris*	Angers quince and quinces in general	—	,,	Bartlett (Williams' Bon Chrétien)	Incompatible.	U.S.A.	22
9	,,	,,	—	,,	,,	Better double-worked.	,,	7
10	,,	,,	seedling	,,	,,	Makes poor union, some breaking and others dying in early years.	California, U.S.A.	95, 191
11	,,	,,	vegetatively	,,	,,	Succeeds on quince, but better on pear.	U.S.A.	174
12	,,	,,	—	,,	,,	Unsatisfactory.	Germany	53, 102, 127
13	,,	,,	vegetatively	,,	Belle Lucrative	Succeeds on quince, but better on pear.	U.S.A.	174
14	,,	,,	—	,,	Beurré d'Amanlis	The variety probably most widely used as an intermediate in double-working.	England	63
15	,,	,,	vegetatively	,,	Beurré d'Anjou	Thrives direct on quince.	U.S.A.	7
16	,,	,,	,,	,,	,,	Succeeds well.	,,	174
17	,,	,,	,,	,,	Beurré d'Arenberg	Succeeds on quince, but better on pear.	,,	174
18	,,	,,	,,	,,	Beurré Bosc	Has to be double-worked.	,,	174

19	,,	,,	—	,,	,,	Unsatisfactory.	Germany	53, 102, 127
20	,,	,,	—	,,	Beurré Clairgeau	,,	,,	53, 102, 127
21	,,	,,	—	,,	,,	Better double-worked.	U.S.A.	7
22	,,	,,	vegetatively	,,	,,	Succeeds well.	,,	174
23	,,	,,	,,	,,	Beurré Diel	Succeeds better than on pear.	,,	174
24	,,	,,	,,	,,	,,	Trees all alive at 25 years, though rather inferior to trees on pear.	South Australia	139
25	,,	,,	—	,,	,,	Suitable for working on quinces.	California, U.S.A.	191
26	,,	,,	—	,,	,,	Union excellent, recommended as an intermediate.	Victoria, Australia.	42
27	,,	,,	—	,,	Beurré Hardy	,,	,,	42
28	,,	,,	—	,,	,,	Perhaps takes more kindly to quince than any other pear variety.	South Africa	43
29	,,	,,		,,	,,	Recommended as intermediate for double-working.	California, U.S.A.	191
30	,,	,,	vegetatively	,,	,,	Succeeds well.	U.S.A.	174
31	,,	,,	,,	,,	Beurré Superfin	,,	,,	174
32	,,	,,	—	,,	Birne von Tongre	Unsatisfactory.	Germany	102, 127
33	,,	,,	vegetatively	,,	Bloodgood	Succeeds well.	U.S.A.	174
34	,,	,,	,,	,,	Buffum	,,	,,	174
35	,,	,,	,,	,,	Colmar	,,	,,	174
36	,,	,,	,,	,,	Columbia	Has to be double-worked.	,,	174
37	,,	,,	,,	,,	Dix	,,	,,	174
38	,,	,,	—	,,	Dr. Jules Guyot	Unsatisfactory.	Germany	53, 102, 127
39	,,	,,	—	,,	Doyenné Boussock	,,	,,	102, 127
40	,,	,,	vegetatively	,,	,,	Succeeds on quince, but better on pear.	U.S.A.	174
41	,,	,,		,,	Doyenné du Comice	Suitable for working on quinces.	California, U.S.A.	191
42	,,	,,		,,	Duchesse d'Angoulême	,,	,,	191

TABLE 1—*continued*

No.	Stock.			Scion.		Behaviour.	Where observed.	Cited from.
	Species.	Variety.	How propagated.	Species.	Variety.			
43	*Cydonia vulgaris*	Angers quince and quinces in general	vegetatively	*P. communis*	Duchesse d'Angoulême	Succeeds better than on pear.	California, U.S.A.	174
44	,,	,,	,,	,,	,,	Thrives direct on quince.	,,	7
45	,,	,,	—	,,	,,	Unsatisfactory.	Germany	53, 102
46	,,	,,	vegetatively	,,	Dunmore	Has to be double-worked.	U.S.A.	174
47	,,	,,	,,	,,	Easter Beurré	Poor growth and cropping, premature decline.	South Australia	139
48	,,	,,	,,	,,	,,	Succeeds better than on pear.	U.S.A.	174
49	,,	,,	—	,,	,,	Suitable for working on quinces.	California, U.S.A.	191
50	,,	,,	—	,,	Edelcrassane	Unsatisfactory.	Germany	53, 102, 127
51	,,	,,	vegetatively	,,	(Manning's) Elisabeth	Thrives direct on quince.	U.S.A.	7, 174
52	,,	,,	,,	,,	Flemish Beauty	Succeeds well.	,,	174
53	,,	,,	,,	,,	Forelle	,,	,,	174
54	,,	,,	,,	,,	Glou Morceau	Succeeds better than on pear.	,,	174
55	,,	,,	,,	,,	,,	Trees all alive at 25 years, though rather inferior to trees on pear.	South Australia	139
56	,,	,,	—	,,	,,	Suitable for working on quinces.	California, U.S.A.	191
57	,,	,,	vegetatively	,,	Gray Doyenné	Succeeds on quince, but better on pear.	U.S.A.	174
58	,,	,,	,,	,,	Howell	Succeeds well.	,,	174
59	,,	,,	,,	,,	,,	Thrives direct on quince.	,,	7
60	,,	,,	,,	,,	Jargonelle	Succeeds well.	,,	174
61	,,	,,	—	,,	,,	Unsatisfactory.	Germany	102, 127
62	,,	,,	vegetatively	,,	Josephine de Malines	Succeeds well.	U.S.A.	174

63	,,	,,	,,	,,	Kingsessing	Succeeds on quince, but better on pear.	,,	174
64	,,	,,	,,	,,	Lamy	Succeeds well.	,,	174
65	,,	,,	,,	,,	Lawrence	Thrives direct on quince.	,,	7
66	,,	,,	,,	,,	,,	Succeeds on quince, but better on pear.	,,	174
67	,,	,,	,,	,,	Louise Bonne de Jersey	Thrives direct on quince.	,,	7
68	,,	,,	,,	,,	,,	Succeeds better than on pear.	,,	174
69	,,	,,	,,	,,	Madeleine	Succeeds well.	,,	174
70	,,	,,	,,	,,	Marie Louise	Has to be double-worked.	,,	174
71	,,	,,	—	,,	,,	Unsatisfactory.	Germany	102, 127
72	,,	,,	—	,,	Olivier de Serres	,,	,,	53, 102
73	,,	,,	vegetatively	,,	Onondaga	Succeeds on quince, but better on pear.	U.S.A.	174
74	,,	,,	,,	,,	Osband	Succeeds well.	,,	174
75	,,	,,	—	,,	P. Barry	Suitable for working on quinces.	California, U.S.A.	191
76	,,	,,	—	,,	Pound	,,	,,	191
77	,,	,,	vegetatively	,,	,,	Succeeds well.	U.S.A.	174
78	,,	,,	,,	,,	Rosteizer	,,	,,	174
79	,,	,,	—	,,	Seckel	Better double-worked.	,,	7
80	,,	,,	vegetatively	,,	,,	Has to be double-worked.	,,	174
81	,,	,,	,,	,,	Sheldon	,,	,,	174
82	,,	,,	—	,,	Souvenir du Congrès	Unsatisfactory.	Germany	102, 127
83	,,	,,		,,	Triomphe de Vienne (Triumph)	,,	,,	53, 127
84	,,	,,	vegetatively	,,	Tyson	Succeeds well.	U.S.A.	174
85	,,	,,	,,	,,	Urbaniste	,,	,,	174
86	,,	,,	,,	,,	Vicar of Winkfield	Succeeds better than on pear.	,,	174
87	,,	,,	,,	,,	Washington	Has to be double-worked.	,,	174

TABLE 1—*continued*

No.	Stock. Species.	Stock. Variety.	Stock. How propagated.	Scion. Species.	Scion. Variety.	Behaviour.	Where observed.	Cited from.
88	*Cydonia vulgaris*	Angers quince and quinces in general	vegetatively	*P. communis*	White Doyenné (Virgalieu)	Succeeds well.	U.S.A.	174
89	,,	,,	,,	,,	,,	Thrives direct on quince.	,,	7
90	,,	,,	—	,,	,,	Suitable for working on quinces.	California, U.S.A.	191
91	,,	,,	—	,,	Winter Bartlett	,,	,,	191
92	,,	,,	—	,,	Winter Nelis	,,	,,	191
93	,,	,,	vegetatively	,,	,,	Has to be double-worked.	U.S.A.	174
94	,,	Quince A (true Angers ?)	layered (clonal)	,,	Most varieties tested	Trees up to 17 years showing no signs of incompatibility.	East Malling, England	2, 75, 78
95	,,	,,	,,	,,	Beurré Clairgeau	Trees weak, clearly unsatisfactory within three years from planting, should be double-worked.	,,	63
96	,,	,,	,,	,,	Dr. Jules Guyot	Trees weak, none too good.	,,	63
97	,,	,,	,,	,,	,,	Trees weak and do not appear really normal.	,,	78
98	,,	,,	,,	,,	Souvenir du Congrès	Trees weak, clearly unsatisfactory within three years from planting, should be double-worked.	,,	63
99	,,	Quince B (Common ?)	,,	,,	Most varieties tested	Trees up to 17 years showing no signs of incompatibility.	,,	2, 75, 78
100	,,	,,	,,	,,	Dr. Jules Guyot	Trees at 10 years abnormally weak.	,,	78
101	,,	Quince C	,,	,,	Most varieties tested	Trees up to 17 years showing no signs of incompatibility.	,,	2, 75, 78
102	,,	,,	,,	,,	Dr. Jules Guyot	Trees at 10 years abnormally weak.	,,	78
103	,,	Quince D (de Fontenay ?)	,,	,,	Conference	Variable take of buds, frail unions, mostly poor growth, premature decline and death	,,	75, 78

104	,,		,,	,,	,,	Dr. Jules Guyot	,,	,,	75, 78
105	,,		,,	,,	,,	Doyenné du Comice	,,	,,	75
106	,,		,,	,,	,,	Durondeau	,,	,,	75, 78
107	,,		,,	,,	,,	Emile d'Heyst	,,	,,	78
108	,,		,,	,,	,,	Fertility	,,	,,	75, 78
109	,,		,,	,,	,,	Pitmaston Duchess	,,	,,	75, 78
110	,,	(?)	Champion quince	,,	,,	Dr. Jules Guyot	Trees stunted, high mortality in early years.	,,	2
111	,,		,,	,,	,,	Reine des Poires	,,	,,	2
112	,,	(?)	Meech's Prolific quince	,,	,,	Dr. Jules Guyot	,,	,,	2
113	,,		,,	,,	,,	Reine des Poires	,,	,,	2
114	,,	(?)	Quince East Malling C.I.	,,	,,	Dr. Jules Guyot	,,	,,	2
115	,,		,,	,,	,,	Reine des Poires	,,	,,	2
116	*C. vulgaris* var. *lusitanica*		Quince E (Portugal Quince)	,,	,,	Conference	Poor growth, premature decline and death of most trees.	,,	75
117	,,		,,	,,	,,	Dr. Jules Guyot	,,	,,	75
118	,,		,,	,,	,,	Doyenné du Comice	,,	,,	75
119	,,		,,	,,	,,	Durondeau	,,	,,	75
120	,,		,,	,,	,,	Emile d'Heyst	,,	,,	75
121	,,		,,	,,	,,	Fertility	,,	,,	75
122	,,		,,	,,	,,	Pitmaston Duchess	,,	,,	75
123	*C. vulgaris* var. *maliformis*		Quince F (Apple-shaped quince)	,,	,,	Conference	,,	,,	75
124	,,		,,	,,	,,	Dr. Jules Guyot	,,	,,	75
125	,,		,,	,,	,,	Durondeau	,,	,,	75

TABLE 1—*continued*

No.	Stock.			Scion.		Behaviour.	Where observed.	Cited from.
	Species.	Variety.	How propagated.	Species.	Variety.			
126	*C. vulgaris* var. *maliformis*	Quince F (Apple-shaped quince)	layered (clonal)	*P. communis*	Emile d'Heyst	Poor growth, premature decline and death of most trees.	East Malling, England	75
127	,,	,,	,,	,,	Fertility	,,	,,	75
128	,,	,,	,,	,,	Pitmaston Duchess	,,	,,	75
129	*C. vulgaris* var. *pyriformis*	Quince G (Pear-shaped quince)	,,	,,	Conference	,,	,,	75
130	,,	,,	,,	,,	Dr. Jules Guyot	,,	,,	75
131	,,	,,	,,	,,	Durondeau	,,	,,	75
132	,,	,,	,,	,,	Emile d'Heyst	,,	,,	75
133	,,	,,	,,	,,	Fertility	,,	,,	75
134	,,	,,	,,	,,	Pitmaston Duchess	,,	,,	75
135	*Pyrus Aria*	White Beam	seedling	,,	Fertility	Growth of trees up to 9 years stunted.	,,	2
136	*P. Aucuparia*	Mountain Ash or Rowan tree	,,	,,	,,	,,	,,	2
137	*P. betulaefolia*	—	,,	,,	Bartlett	Outstanding vigour and size in trees at 6-7 years.	N.Y. State, U.S.A.	176, 179, 180
138	,,	—	,,	,,	,,	Union perfect, trees at 6 years vigorous.	Oregon, U.S.A.	142
139	,,	—	,,	,,	Beurré d'Anjou	Uncongenial, trees weak, some mortality within 6 years.	N.Y. State, U.S.A.	176, 179, 180
140	,,	—	,,	,,	,,	Union perfect, trees at 6 years vigorous.	Oregon, U.S.A.	142
141	,,	—	,,	,,	Beurré Bosc	Slight enlargement below union, but trees at 6 years vigorous.	,,	142
142	,,	—	,,	,,	Doyenné du Comice	Considerable enlargement above union, but trees at 6 years vigorous.	,,	142
143	,,	—	,,	,,	Howell	Slight enlargement below union, but trees at 6 years vigorous.	,,	142

144	,,	—	,,	,,	Old Home	Union perfect, trees very vigorous.	,,	142
145	,,	—	,,	,,	Seckel	Outstanding vigour and size in trees at 6-7 years.	N.Y. State, U.S.A.	176, 179, 180
146	,,	—	,,	,,	Winter Nelis	Union good, trees at 6 years vigorous.	Oregon, U.S.A.	142
147	,,	—	,,	*P. communis* × *P. serotina*	Kieffer	Outstanding vigour and size in trees at 6-7 years.	N.Y. State, U.S.A.	176, 179, 180
148	*P. calleryana*	—	,,	*P. communis*	Pears in general	Promising.	Victoria, Australia	42
149	,,	—	,,	,,	,,	Excellent.	Tennessee, U.S.A.	46
150	,,	—	,,	,,	Various varieties	Trees very variable, some good, others very poor; a high proportion had to be replanted.	Michigan, U.S.A.	104
151	,,	—	,,	,,	Bartlett	Union good, but trees weak, worthless, some mortality within 6 years, due mainly to winter injury.	N.Y. State, U.S.A.	176, 179, 180
152	,,	—	—	,,	,,	Relatively low % take of buds held to indicate partial incompatibility.	Hangchow, China	23
153	,,	—	seedling	,,	,,	Union perfect, trees at 6 years very vigorous.	Oregon, U.S.A.	142
154	,,	—	—	,,	Beurré d'Anjou	Union good, but trees weak, worthless, some mortality within 6 years due mainly to winter injury.	N.Y. State, U.S.A.	176, 179, 180
155	,,	—	seedling	,,	,,	Union perfect, trees at 6 years very vigorous.	Oregon, U.S.A.	142
156	,,	—	,,	,,	Beurré Bosc	Union strong, apparently congenial, trees at 6 years very vigorous.	,,	142
157	,,	a few selections	layered (clonal)	,,	Dr. Jules Guyot	Trees vigorous, no sign of incompatibility at 6 years.	East Malling, England	2
158	,,	—	seedling	,,	Doyenné du Comice	Scion outgrows stock, but trees at 6 years vigorous.	Oregon, U.S.A.	142
159	,,	—	,,	,,	Howell	Union strong, apparently congenial, trees at 6 years very vigorous.	,,	142
160	,,	—	—	,,	Seckel	Union good, but trees weak, worthless, some mortality within 6 years due mainly to winter injury.	N.Y. State, U.S.A.	176, 179, 180
161	,,	—	seedling	,,	Winter Nelis	Union strong, apparently congenial, trees at 6 years very vigorous.	Oregon, U.S.A.	142

TABLE I—*continued*

No.	Stock.			Scion.		Behaviour.	Where observed.	Cited from.
	Species.	Variety.	How propagated.	Species.	Variety.			
162	*P. calleryana*	—	seedling	*P. communis* × *P. serotina*	Kieffer	Union good, but trees weak, worthless, some mortality within 6 years, due mainly to winter injury.	N.Y. State, U.S.A.	176, 179, 180
163	*P. communis*	"French" pear	,,	*P. calleryana*	Oroville type	Union appears satisfactory.	California, U.S.A.	141
164	,,	pears in general	,,	*P. communis*	pears in general	Generally regarded as entirely congenial.	Various	Various
165	,,	selections	layered (clonal)	,,	Dr. Jules Guyot	14 out of 18 selections appear entirely congenial.	East Malling, England	2, 78
166	,,	Old Home	top-worked	,,	Leading local varieties	Forms strong unions.	Oregon, U.S.A.	142
167	,,	Pear selection A2	layered (clonal)	,,	Dr. Jules Guyot	Trees very stunted from outset and all died in first 2-3 years.	East Malling, England	2, 77
168	,,	Pear selection A3	,,	,,	,,	Trees at 9 years small, and in early autumn foliage turns abnormal colour—suggests delayed incompatibility.	,,	2
169	,,	,,	,,	,,	Reines des Poires	,,	,,	2
170	,,	Pear selection C3	,,	,,	Dr. Jules Guyot	Growth of trees declined markedly after first year and some started dying.	,,	2, 77
171	,,	"French" pear	seedling	*P. communis* × *P. serotina*	Garber	Scion soon overgrows the stock.	U.S.A.	7
172	,,	,,	,,	,,	Le Conte	,,	,,	7
173	,,	,,	,,	,,	Kieffer	,,	,,	7
174	,,	,,	,,	,,	,,	Trees variable, much weaker than trees on own roots raised from cuttings and some mortality in early years.	N.Y. State, U.S.A.	175, 176
175	,,	,,	,,	,,	Smith	Scion soon overgrows the stock.	U.S.A.	7
176	*P. communis* × *P. serotina*	Estella	top-worked	*P. communis*	Bartlett	Makes a good body stock.	Oregon, U.S.A.	142

177	,,	,,	,,	,,	Beurré d'Anjou	,,	,,	142
178	,,	,,	,,	,,	Beurré Bosc	Uncongenial.	,,	142
179	,,	Kieffer	,,	,,	Leading local varieties	Forms strong unions.	,,	142
180	*P. Koehnei*	—	seedling	,,	,,	Trees at 8 years vigorous, unions so far very satisfactory.	,,	142
181	*P. Malus*	Apple	,,	,,	Pears in general	Very uncongenial, showing early death or breaking at union.	Michigan, U.S.A.	17
182	,,	,,	,,	,,	,,	Trees very short-lived.	U.S.A.	7
183	,,	,,	seedling and top-worked	,,	,,	Trees may flourish for a time but rarely long-lived.	South Africa	43
184	,,	,,	top-worked	,,	,,	,,	California, U.S.A.	193
185	*P. Pashia* × *P. communis*	Variolosa	,,	,,	Leading local varieties	Forms strong union.	Oregon, U.S.A.	142
186	*P. serotina*	Chinese Sand pear	seedling	*Pyrus* spp.	Almost all known	Produces strong union and satisfactory growth.	,,	142
187	,,	,,	—	*P. communis*	Pears in general	Unsuitable.	U.S.A.	153
188	,,	,,	seedling	,,	Several varieties	Produces good unions and growth.	Michigan, U.S.A.	104
189	,,	,,	,,	,,	Bartlett	Trees weak, some mortality within 6 years.	N.Y. State, U.S.A.	176, 179, 180
190	,,	,,	,,	,,	,,	Union strong, trees vigorous.	Oregon, U.S.A.	142
191	,,	,,	,,	,,	Beurré d'Anjou	,,	,,	142
192	,,	,,	,,	,,	Beurré Bosc	,,	,,	142
193	,,	,, (a few selections)	layered (clonal)	,,	Dr. Jules Guyot	No sign of incompatibility in trees at 6 years.	East Malling, England	2
194	,,	Chinese Sand pear	seedling	,,	Doyenné du Comice	Union strong, trees vigorous.	Oregon, U.S.A.	142
195	,,	,,	,,	,,	Howell	,,	,,	142
196	,,	,,	,,	,,	Old Home	,,	,,	142
197	,,	,,	,,	,,	Seckel	Trees weak, some mortality within 6 years.	N.Y. State, U.S.A.	176, 179, 180
198	,,	,,	,,	,,	Winter Nelis	Union strong, trees vigorous.	Oregon, U.S.A.	142

TABLE 1—*continued*

No.	Stock.			Scion.		Behaviour.	Where observed.	Cited from.
	Species.	Variety.	How propagated.	Species.	Variety.			
199	*P. serotina*	Chinese Sand pear	seedling	*P. communis* × *P. serotina*	Kieffer	Trees satisfactory at 6-7 years, superior to trees on *P. communis*.	N.Y. State, U.S.A.	176, 179, 180
200	,,	,,	,,	*P. Pashia* × *P. communis*	Variolosa	Union strong, trees vigorous.	Oregon, U.S.A.	142
201	*P. serrulata*	a few selections	layered (clonal)	*P. communis*	Dr. Jules Guyot	Trees vigorous, no sign of incompatibility at 6 years.	East Malling, England	2
202	*P. sinensis*	—	seedling	*P. calleryana*	Oroville type	Union appears satisfactory.	California, U.S.A.	141
203	*P. Torminalis*	Wild Service	,,	*P. communis*	Fertility	Trees up to 9 years old stunted.	East Malling, England	2
204	*P. ussuriensis*	—	—	,,	Pears in general	Unsuitable.	U.S.A.	153
205	,,	wild types	seedling	,,	Several varieties	Scion soon overgrows stock and breaks off at union, but seed from named varieties may be satisfactory.	Oregon and Michigan, U.S.A.	104, 142
206	,,	not stated	,,	,,	Bartlett	Trees at first vigorous, then rather weak, some mortality within 6 years.	N.Y. State, U.S.A.	176, 179, 180
207	,,	,,	,,	,,	Beurré d'Anjou	Trees at first vigorous, then very weak, some mortality within 6 years.	,,	176, 179, 180
208	,,	,,	,,	,,	Seckel	Trees at first vigorous, then rather weak, some mortality within 6 years.	,,	176, 179, 180
209	,,	,,	,,	*P. communis* × *P. serotina*	Kieffer	Trees at 6-7 years large and vigorous, superior to trees on *P. communis*.	,,	176, 179, 180

TABLE 2

ROOTSTOCKS TESTED FOR PLUMS, *PRUNUS AMERICANA*, *P. CERASIFERA*, *P. DOMESTICA*, *P. HORTULANA*, *P. INSITITIA*, *P. MUNSONIANA*, *P. SALICINA* AND HYBRIDS

No.	Stock.			Scion.		Behaviour.	Where observed.	Cited from.
	Species.	Variety.	How propagated.	Species.	Variety.			
1	*P. americana*	—	seedling	*P. americana*	De Soto	Trees at 10 years had grown and fruited well.	N.Y. State, U.S.A.	84
2	,,	—	,,	*P. domestica*	European plums in general	Tops tend to outgrow the stock, become top heavy, break off at the union, or die back.	Canada	121
3	,,	cultivated types	,,	,,	Black Prune	Best stock for western districts.	U.S.A.	19
4	,,	,,	,,	,,	Hungarian (Ungarish)	,,	,,	19
5	,,	—	—	*P. Munsoniana*	Newman	Did well, though dwarfed.	Vermont, U.S.A.	170, 185
6	,,	—	—	*P. Munsoniana* × ?	Milton	Did very well, though dwarfed.	,,	170, 185
7	,,	—	—	*P. salicina*	Chabot	Grew well, though dwarfed.	,,	170, 185
8	,,	—	seedling	*P. salicina* × *P. americana*	Hybrid plums	Excellent if budded low.	Minnesota, U.S.A.	1
9	*P. Amygdalus*	Almonds in general	,,	*P. domestica*	European plums in general	Some combinations fail, others succeed.	California, U.S.A.	191
10	,,	,,	—	,,	Most prunes	Makes strong union.	,,	89
11	,,	,,	top-worked	,,	Burton (Prune)	Questionable, some trees doing well.	,,	90
12	,,	,,	,,	,,	California Blue (Vacaville)	Total failure.	,,	90
13	,,	,,	,,	,,	Clyman	Proved compatible.	,,	90, 91
14	,,	,,	,,	,,	Diamond	Questionable, some trees doing well.	,,	90
15	,,	,,	various	,,	French Prune (Prune d'Agen)	Trees succeed admirably.	,,	90, 91, 191

TABLE 2—*continued*

No.	Stock.			Scion.		Behaviour.	Where observed.	Cited from.
	Species.	Variety.	How propagated.	Species.	Variety.			
16	*P. Amygdalus*	Almonds in general	seedling	*P. domestica*	Grand Duke	Trees at 8 years normal-sized, healthy.	California, U.S.A.	45
17	,,	,,	top-worked	,,	Hungarian	Proved compatible.	,,	90, 91
18	,,	,,	,,	,,	Imperial	Questionable, some trees doing well.	,,	90
19	,,	,,	various	,,	President	Takes well and proved compatible.	,,	90, 91, 191
20	,,	,,	top-worked	,,	Robe de Sergeant	Total failure.	,,	90
21	,,	,,	,,	,,	,,	Trees do not show strong affinity.	,,	89
22	,,	,,	,,	,,	Standard (Prune)	Proved compatible.	,,	90, 91
23	,,	,,	seedling	,,	Stewart	Takes well.	,,	191
24	,,	,,	top-worked	,,	Tragedy	Proved compatible.	,,	90, 91
25	,,	,,	,,	*P. salicina*(?)	Apex	,,	,,	90, 91
26	,,	,,	seedling	,, (?)	Beauty	Makes unsuccessful union.	,,	137
27	,,	,,	top-worked	,,	Burbank	Questionable, some trees doing well.	,,	90
28	,,	,,	,,	,, (?)	Duarte	Proved compatible.	,,	90, 91
29	,,	,,	,,	,,	Kelsey	Questionable, some trees doing well.	,,	90
30	,,	,,	,,	,,	Santa Rosa	,,	,,	90
31	,,	,,	—	,,	,,	Makes a good union.	,,	137
32	,,	,,	top-worked	*P. salicina* × ?	Formosa	Shows affinity.	,,	90, 91
33	,,	,,	,,	*P. salicina* × *P. americana*	Gaviota	Questionable, some trees doing well.	,,	90
34	,,	,,	,,	*P. salicina* × *P. Simonii*	Climax	,,	,,	90
35	,,	,,	,,	,,	Wickson	,,	,,	90
36	,,	Drake	,,	*P. domestica*	Sugar (Prune)	Practically all grafts died within 3 years.	,,	90, 91

37	,,	Eureka	,,	,,	,,	Trees in good condition after 7 years.	,,	90, 91
38	,,	I.X.L.	,,	,,	,,	Practically all grafts died within 3 years.	,,	90, 91
39	,,	Ne Plus Ultra	,,	,,	,,	Trees in good condition after 7 years.	,,	90, 91
40	,,	Nonpareil	,,	,,	,,	Practically all grafts died within 3 years.	,,	90, 91
41	,,	Peerless	,,	,,	,,	,,	,,	90, 91
42	*P. Armeniaca*	Apricots in general	seedling	,,	Plums in general	Some make good trees, others fail, breaking off at the union, etc.	,,	191
43	,,	,,	top-worked	,,	,,	Failure to form union common, and where successful trees are rarely as satisfactory as those on some other stocks.	,,	90
44	,,	,,	seedling	,,	,,	Trees may snap off at the union in high winds, otherwise an excellent stock.	South Africa	43
45	,,	,,	various	,,	Some prunes	Tend to make poor unions.	California, U.S.A.	89
46	,,	,,	seedling	,,	Angelina Burdett	Trees at 10 years larger than those on Myrobalan.	N.S.W., Australia	32
47	,,	,,	,,	,,	Blue Imperatrice	,,	,,	32
48	,,	,,	top-worked	,,	Burton (Prune)	A number of good trees have been made.	California, U.S.A.	90
49	,,	,,	,,	,,	Clyman	,,	,,	90
50	,,	,,	,,	,,	French Prune (Prune d'Agen)	,,	,,	90
51	,,	,,	seedling	,,	,,	Trees at 10 years larger than those on Myrobalan	N.S.W., Australia	32
52	,,	,,	,,	,,	,,	Union very poor, many trees breaking off at different ages.	California, U.S.A.	96
53	,,	,,	top-worked	,,	Giant	A number of good trees have been made.	,,	90
54	,,	,,	seedling	,,	Grand Duke	9-year-old trees normal-sized, healthy.	,,	45
55	,,	,,	,,	,,	,,	Trees at 10 years larger than those on Myrobalan.	N.S.W., Australia	32
56	,,	,,	,,	,,	President	,,	,,	32
57	,,	,,	top-worked	,,	Quackenboss	A number of good trees have been made.	California, U.S.A.	90

TABLE 2—*continued*

No.	Stock.			Scion.		Behaviour.	Where observed.	Cited from.
	Species.	Variety.	How propagated.	Species.	Variety.			
58	*P. Armeniaca*	Apricots in general	seedling	*P. domestica*	Robe de Sergeant	Trees at 10 years larger than those on Myrobalan.	N.S.W., Australia	32
59	,,	,,	,,	,,	Standard (Prune)	,,	,,	32
60	,,	,,	,,	,,	Sugar (Prune)	Takes kindly to apricot.	California, U.S.A.	191
61	,,	,,	top-worked	,,	,,	A number of good trees have been made.	,,	90
62	,,	,,	,,	,,	Tragedy	,,	,,	90
63	,,	,,	seedling	*P. salicina* and hybrids	Japanese plums in general	An excellent stock, except for snapping at unions in high winds.	South Africa	43
64	,,	,,	top-worked	,,	,,	Often fail to form union, and where successful trees are rarely as satisfactory as those on some other stocks.	California, U.S.A.	90
65	,,	,,	,,	*P. salicina*	Kelsey	A number of good trees have been made.	,,	90
66	,,	,,	,,	,,	Satsuma	,,	,,	90
67	,,	,,	,,	*P. salicina* × *P. Simonii*	Wickson	,,	,,	90
68	*P. cerasifera*	Myrobalan	seedling	*P. americana*	De Soto	Trees at 10 years old had grown very well.	N.Y. State, U.S.A.	84
69	,,	,,	,,	*P. cerasifera*	Myrobalan or Cherry Plum	Rather low % take of buds (1)*.	East Malling, England	2
70	,,	,,	,,	*P. domestica*	Plums in general	Makes good unions and trees.	Victoria, Australia	42
71	,,	,,	,,	,,	Prunes in general	Regarded as approaching the normal union internally.	California, U.S.A.	136
72	,,	,,	,,	,,	5 varieties tested	Trees vigorous at 10 years old.	N.Y. State, U.S.A.	84
73	,,	,,	,,	,,	Most prunes	Make strong unions.	California, U.S.A.	89
74	,,	,,	,,	,,	Most varieties	,,	,,	90

* The figure in brackets refers to the number of seasons in which the combination was tested.

75	,,	,,	,,	,,	5 varieties tested	Good % take of buds.	East Malling, England	2, 73
76	,,	,,	,,	,,	Czar	Trees at 4 years very vigorous.	,,	80
77	,,	,,	,,	,,	French Prune (Prune d'Agen)	Scion tends to overgrow stock.	U.S.A.	22
78	,,	,,	,,	,,	Grand Duke	Trees at 8 years healthy and normal-sized.	California, U.S.A.	45
79	,,	,,	,,	,,	Robe de Sergeant	Not entirely satisfactory.	U.S.A.	22
80	,,	,,	various	,,	,,	Unsatisfactory.	California, U.S.A.	90
81	,,	,,	seedling	*P. hortulana*	Forest Garden	Trees at 10 years old vigorous.	N.Y. State, U.S.A.	84
82	,,	,,	,,	,,	Wayland	,,	,,	84
83	,,	,,	,,	*P. insititia*	Black Bullace	Rather low % take of buds (1).	East Malling, England	2, 73
84	,,	,,	,,	,,	Drap d'Or	Trees at 10 years old had grown and fruited better than on other stocks.	N.Y. State, U.S.A.	84
85	,,	,,	,,	,,	Prune Damson	Good % take of buds.	East Malling, England	2, 73
86	,,	,,	,,	,,	Shropshire	Trees at 10 years old had grown better than on other stocks.	N.Y. State, U.S.A.	84
87	,,	,,	,,	*P. Munsoniana*	Pottawattamie	Trees at 10 years old had grown and fruited well.	,,	84
88	,,	,,	,,	,,	Wild Goose	,,	,,	84
89	,,	,,	,,	*P. salicina*	Most Japanese varieties	Lacks affinity and is unsuccessful.	South Africa	43
90	,,	,,	,,	,,	Most varieties	Shows affinity.	California, U.S.A.	90
91	,,	,,	,,	,,	Abundance	Trees at 10 years old had grown vigorously but fruited poorly.	N.Y. State, U.S.A.	84
92	,,	,,	,,	,,	Burbank	Trees at 10 years old had grown and fruited better than on other stocks.	,,	84
93	,,	,,	,,	,,	Chabot	,,	,,	84
94	,,	,,	,,	,,	Kelsey	Does well.	South Africa	43
95	,,	Myrobalan B	layered (clonal)	*P. domestica*	10 varieties tested	Fair to high % take of buds.	East Malling, England	2
96	,,	,,	,,	,,	Pond's Seedling	Rather low % take of buds (1).	,,	2

TABLE 2—*continued*

No.	Stock. Species.	Variety.	How propagated.	Scion. Species.	Variety.	Behaviour.	Where observed.	Cited from.
97	*P. cerasifera*	Myrobalan B	layered (clonal)	*P. insititia*	Bradley's King	Fair to high % take of buds (2).	East Malling, England	2
98	*P. cerasifera* var. *divaricata*	29 families	seedling	*P. domestica*	Czar	3 buds were inserted in each of 150 seedlings, and in only 8 cases did all 3 buds fail on an individual. One scion shoot broke off at the union, indicating that some incompatibility may be found.	,,	181
99	*P. cerasifera* × *P. Munsoniana*	Marianna (Mariana)	cuttings (clonal)	*P. cerasifera*	Myrobalan or Cherry Plum	Complete failure to unite (1).	,,	2
100	,,	,,	seedling	*P. domestica*	Angelina Burdett	Trees very weak and tended to overbear.	N.S.W., Australia	31, 32
101	,,	,,	cuttings (clonal)	,,	Belle de Louvain	Fair % take of buds (1).	East Malling, England	2, 73
102	,,	,,	,,	,,	Czar	Low % take of buds (3+).	,,	2, 73
103	,,	,,	,,	,,	,,	Heavy loss of both grafted and budded trees by end of second year.	,,	2
104	,,	,,	,,	,,	,,	Some deaths among trees up to 11 years old suggest delayed incompatibility.	,,	79
105	,,	,,	,,	,,	Early Rivers (River's Early Prolific)	Failed to unite when budded (1)	,,	2, 73
106	,,	,,	,,	,,	Giant Prune	High % take of buds (1).	,,	2, 73
107	,,	,,	,,	,,	Martin's Purple Egg	Fair % take of buds (1) and no deaths to 11 years old.	,,	2
108	,,	,,	,,	,,	Pershore Yellow Egg	Good % take of buds (1).	,,	2, 73
109	,,	,,	seedling	,,	President	Trees very weak and tended to overbear.	N.S.W., Australia	31, 32
110	,,	,,	cuttings (clonal)	,,	,,	Good % take of buds (1).	East Malling, England	73

111	,,	,,	,,	,,	,,	Some trees, died, incompatible, within 14 years.	,,	2
112	,,	,,	,,	,,	Utility	High % take of buds (1) and no deaths to 11 years old.	,,	2
113	,,	,,	,,	,,	Victoria	High % take of buds and grafts in 6 years, low in 2. No deaths within 14 years.	,,	2, 73
114	,,	,,	seedling	*P. hortulana*	Forest Garden	Proved one of the best of several stocks up to 10 years old.	N.Y. State, U.S.A.	84
115	,,	,,	,,	,,	Wayland	,,	,,	84
116	,,	,,	cuttings (clonal)	*P. insititia*	Black Bullace	Failed to unite when budded (1).	East Malling, England	2, 73
117	,,	,,	,,	,,	Bradley's King	Very low % take of buds or total failure to unite, and no trees surviving after 2 years (2).	,,	2
118	,,	,,	,,	,,	Prune Damson	Failed to unite when budded (1).	,,	2, 73
119	,,	,,	—	*P. Munsoniana*	Newman	Did well.	Vermont, U.S.A.	170, 185
120	,,	,,	seedling	,,	Pottawattamie	Proved one of the best of several stocks up to 10 years old.	N.Y. State, U.S.A.	84
121	,,	,,	,,	,,	Wild Goose	,,	,,	84
122	,,	,,	—	*P. Munsoniana* × ?	Milton	Did well.	Vermont, U.S.A.	170, 185
123	,,	,,	—	*P. salicina*	Chabot	Satisfactory.	,,	170, 185
124	*P. domestica*	Plums in general	—	*P. cerasifera*	Myrobalan or Cherry Plum	Appears to thrive.	California, U.S.A.	90
125	,,	Brompton	layered (clonal)	,,	,,	Fair % take of buds (1).	East Malling, England	2, 73
126	,,	,,	,,	*P. domestica*	8 varieties tested	% take of buds fair to high.	,,	2, 73, 80
127	,,	,,	,,	,,	Giant Prune	Rather low % take of buds (1).	,,	2, 73
128	,,	,,	,,	*P. insititia*	Black Bullace	Fair % take of buds (1).	,,	2, 73
129	,,	,,	,,	,,	Bradley's King	,, (1).	,,	2
130	,,	,,	,,	,,	Prune Damson	Failed to unite when budded (1).	,,	2, 73
131	,,	Brussels (Brussel)	,,	*P. cerasifera*	Myrobalan or Cherry Plum	Very low % take of buds (1).	,,	2, 73

TABLE 2—*continued*

No.	Stock.			Scion.		Behaviour.	Where observed.	Cited from.
	Species.	Variety.	How propagated.	Species.	Variety.			
132	*P. domestica*	Brussels (Brussel)	layered (clonal)	*P. cerasifera*	Myrobalan or Cherry Plum	Growth weak.	East Malling, England.	74
133	,,	,,	,,	*P. domestica*	Czar	Low % take of buds, and heavy loss of trees by end of second season through breakages, etc. (3+).	,,	2, 80
134	,,	,,	,,	,,	,,	Growth of trees weak.	,,	74
135	,,	,,	,,	,,	,,	Some deaths among trees up to 11 years old suggest delayed incompatibility.	,,	79
136	,,	,,	,,	,,	Denniston's Superb Gage	Low % take of buds (1).	,,	2, 73
137	,,	,,	,,	,,	Early Rivers (River's Early Prolific)	High % take of buds (1) and trees all alive at 14 years, but small and low cropping.	,,	2, 73
138	,,	,,	,,	,,	Giant Prune	Fair % take of buds (1).	,,	2, 73
139	,,	,,	,,	,,	Martin's Purple Egg	Rather low % take of buds (2).	,,	2, 73
140	,,	,,	,,	,,	,,	Growth of trees weak.	,,	74
141	,,	,,	,,	,,	Pershore Yellow Egg	Rather low % take of buds (1).	,,	2, 73
142	,,	,,	,,	,,	Pond's Seedling	,,	,,	2
143	,,	,,	,,	,,	President	Many trees dead or broken off at unions at 14 years after budding.	,,	2
144	,,	,,	,,	,,	,,	Trees stunted, unthrifty, many premature deaths.	,,	79
145	,,	,,	,,	,,	Victoria	Fair to high % take of buds and grafts, and trees all alive at 14 years, but relatively small and low cropping.	,,	2, 73
146	,,	,,	,,	*P. insititia*	Black Bullace	Very low % take of buds (2).	,,	2, 73

147	,,	,,	,,	,,	,,	All trees dead or broken off at unions by end of second year.	,,	2
148	,,	,,	,,	,,	Bradley's King	Very low % take of buds (3), and all dead or broken off at unions by end of second year.	,,	2
149	,,	,,	,,	,,	Cluster Damson	All trees dead or broken off at unions within 2 years.	,,	2
150	,,	,,	,,	,,	Frogmore	Rather low % take of buds (1), and all dead or broken off at unions within 2 years.	,,	2
151	,,	,,	,,	,,	Langley Bullace	All trees dead or broken off at unions within 2 years.	,,	2
152	,,	,,	,,	,,	Merry-weather	Rather low % take of buds (1), and all trees dead or broken off at unions within 2 years.	,,	2
153	,,	,,	,,	,,	Prune Damson	Variable % take, and all dead or broken off at unions within 2 years.	,,	2, 73
154	,,	,,	,,	,,	Shepherd's Bullace	All trees dead or broken off at unions within 2 years.	,,	2
155	,,	California Blue (Vacaville)	top-worked	*P. domestica*	All types tested	Scions often unite and start growing, but soon weaken, cease growth, and die.	California, U.S.A.	90
156	,,	,,	,,	*P. salicina* and hybrids	,,	,,	,,	90
157	,,	Clyman	,,	*P. domestica*	Almost all varieties tested	Owing to its compatibility with other plums Clyman is frequently used as an intermediate stock in double-working.	,,	90
158	,,	,,	,,	,,	California Blue (Vacaville)	Unsatisfactory.	,,	90
159	,,	,,	,,	*P. salicina*	Almost all varieties tested	Owing to its compatibility with other plums Clyman is frequently used as an intermediate stock in double-working.	,,	90
160	,,	Common Plum	layered (clonal)	*P. cerasifera*	Myrobalan or Cherry Plum	Low % take of buds (1).	East Malling, England	2, 73
161	,,	,,	,,	*P. domestica*	Belle de Louvain	Fair % take of buds (1).	,,	2
162	,,	,,	,,	,,	Czar	Low % take of buds in many seasons (3+).	,,	2, 73

TABLE 2—*continued*

No.	Stock.			Scion.		Behaviour.	Where observed.	Cited from.
	Species.	Variety.	How propagated.	Species.	Variety.			
163	*P. domestica*	Common Plum	layered (clonal)	*P. domestica*	Czar	Trees very weak.	East Malling, England.	2, 73
164	,,	,,	,,	,,	,,	Low % take, or dwarf trees surviving only a few years (some exceptions).	,,	80
165	,,	,,	,,	,,	Denniston's Superb Gage	Fair % take of buds (1).	,,	2
166	,,	,,	,,	,,	Early Rivers (River's Early Prolific)	Fair % take of buds (1), trees all alive at 14 years, but weak and low cropping.	,,	2
167	,,	,,	,,	,,	Giant Prune	Rather low % take of buds (1).	,,	2
168	,,	,,	,,	,,	Martin's Purple Egg	Good % take of buds (1), trees all alive at 11 years, but weak and low cropping.	,,	2
169	,,	,,	,,	,,	Monarch	Good % take of buds (1).	,,	2
170	,,	,,	,,	,,	Pershore Yellow Egg	,, (1)	,,	2
171	,,	,,	,,	,,	Pond's Seedling	Very low % take of buds (1).	,,	2
172	,,	,,	,,	,,	President	Many trees dead or broken off at unions 14 years after budding.	,,	2
173	,,	,,	,,	,,	,,	Trees stunted, unthrifty, many premature deaths.	,,	79
174	,,	,,	,,	,,	Utility	Good % take of buds (1), trees all alive at 11 years, relative growth and cropping fair.	,,	2
175	,,	,,	,,	,,	Victoria	% take of buds and grafts mostly fair to high (3+), trees all alive at 14 years, growth weak, cropping medium.	,,	2, 73
176	,,	,,	,,	*P. insititia*	Black Bullace	Low % take of buds (2), and all dead or broken off at unions within 2 years.	,,	2, 73
177	,,	,,	,,	,,	Bradley's King	Rather low % take of buds (3), and all dead or broken off at unions within 2 years.	,,	2

178	,,	,,	,,	,,	Cluster Damson	All trees dead or broken off at unions within 2 years.	,,	
179	,,	,,	,,	,,	Frogmore	,,	,,	2
180	,,	,,	,,	,,	Langley Bullace	,,	,,	2
181	,,	,,	,,	,,	Merry-weather	,,	,,	2
182	,,	,,	,,	,,	Prune Damson	Low % take of buds (2), and all dead or broken off at unions within 2 years.	,,	2, 73
183	,,	,,	,,	,,	Shepherd's Bullace	All trees dead or broken off at unions within 2 years.	,,	2
184	,,	Diamond	top-worked	*P. domestica*	Most varieties tested	Do well.	California, U.S.A.	90
185	,,	,,	,,	,,	California Blue (Vacaville)	Unsatisfactory.	,,	90
186	,,	,,	,,	*P. salicina*	Most varieties tested	Do well.	,,	90
187	,,	French Prune (d'Agen)	,,	*P. domestica*	,,	This stock is sometimes used as an intermediate.	,,	90
188	,,	,,	,,	,,	California Blue (Vacaville)	Shows possible incompatibility.	,,	90
189	,,	,,	,,	*P. salicina*	Most varieties tested	This stock is sometimes used as an intermediate.	,,	90
190	,,	Giant Prune	,,	*P. domestica*	,,	A good all-round stock.	,,	90
191	,,	,,	,,	,,	California Blue (Vacaville)	Incompatible.	,,	90, 91
192	,,	,,	,,	*P. salicina*	Most varieties tested	A good all-round stock.	,,	90
193	,,	Grand Duke	,,	*P. domestica*	,,	,,	,,	90
194	,,	,,	,,	,,	President	Unsatisfactory.	,,	90
195	,,	,,	,,	*P. salicina*	Most varieties tested	A good all-round stock.	,,	90
196	,,	Hungarian	,,	*P. domestica*	,,	,,	,,	90

TABLE 2—*continued*

No.	Stock.			Scion.		Behaviour.	Where observed.	Cited from.
	Species.	Variety.	How propagated.	Species.	Variety.			
197	*P. domestica*	Hungarian	top-worked	*P. domestica*	California Blue (Vacaville)	Unsatisfactory.	California, U.S.A.	90
198	,,	,,	,,	,,	Grand Duke	Shows lack of affinity.	,,	91
199	,,	,,	,,	,,	President	Results variable.	,,	90
200	,,	,,	,,	*P. salicina*	All varieties tested	A good all-round stock.	,,	90
201	,,	Kroosjespruim	layered (clonal)	*P. domestica*	Czar	Heavy loss of both grafted and budded trees within 2 years.	East Malling, England	2
202	,,	,,	,,	,,	Victoria	Fair % take of buds (1).	,,	2
203	,,	,,	,,	*P. insititia*	Bradley's King	Failed to unite when budded (1).	,,	2
204	,,	Merunka	seedling	*P. domestica*	German Prune (Zwetsche)	Makes healthy growth.	Germany	158
205	,,	Pershore	layered (clonal)	*P. cerasifera*	Myrobalan or Cherry plum	Medium % take of buds (1).	East Malling, England	2, 73
206	,,	,,	,,	*P. domestica*	6 varieties	Fair to high % take of buds (1 to 3).	,,	2, 73
207	,,	,,	,,	,,	Denniston's Superb Gage	Rather low % take of buds (1).	,,	2, 73
208	,,	,,	,,	*P. insititia*	3 varieties	Medium to good % take of buds (1).	,,	2, 73
209	,,	President	top-worked	*P. domestica*	Most varieties tested	Successful.	California, U.S.A.	90
210	,,	,,	,,	,,	California Blue (Vacaville)	Unsuccessful.	,,	90
211	,,	,,	,,	*P. salicina*	Most varieties tested	Successful.	,,	90
212	,,	Quackenboss	,,	*P. domestica*	,,	,,	,,	90
213	,,	,,	,,	,,	President	Results variable.	,,	90

214	,,	,,	,,	*P. salicina*	Most varieties tested	Successful.	,,	90
215	,,	Robe de Sergeant	,,	*P. domestica*	Grand Duke	Trees at 8 years normal-sized, healthy.	,,	45
216	,,	Standard (Prune)	,,	,,	Most varieties tested	Successful.	,,	90
217	,,	,,	,,	*P. salicina*	,,	,,	,,	90
218	,,	Sugar Prune	,,	*P. domestica*	,,	,,	,,	90
219	,,	,,	,,	,,	California Blue (Vacaville)	Unsatisfactory.	,,	90
220	,,	,,	,,	*P. salicina*	Most varieties tested	Successful.	,,	90
221	,,	Tragedy (Prune)	,,	*P. domestica*	,,	Made good unions.	,,	90
222	,,	,,	,,	,,	California Blue (Vacaville)	Unsatisfactory.	,,	90
223	,,	,,	,,	*P. salicina*	Most varieties tested	Made good unions.	,,	90
224	*P. hortulana*	Wayland	—	*P. domestica*	Reine Claude (Green Gage)	Did well.	Vermont, U.S.A.	170
225	,,	,,	—	*P. Munsoniana*	Newman	,,	,,	170
226	,,	,,	—	*P. Munsoniana* × ?	Milton	Did very well.	,,	170
227	,,	,,	—	*P. salicina*	Chabot	Grew well.	,,	170
228	*P. insititia*	Broad-leaved Shiny Mussel	layered (clonal)	*P. domestica*	Czar	Good to high % take of buds and grafts (3+), and trees all alive at 11 years.	East Malling, England	2
229	,,	,,	,,	,,	Early Rivers (River's Early Prolific)	Very high % take (1), trees all alive at 14 years.	,,	2, 73
230	,,	,,	,,	,,	Giant Prune	Rather low % take of buds (1).	,,	2

TABLE 2—*continued*

No.	Stock. Species.	Stock. Variety.	Stock. How propagated.	Scion. Species.	Scion. Variety.	Behaviour.	Where observed.	Cited from.
231	*P. insititia*	Broad-leaved Shiny Mussel	layered (clonal)	*P. domestica*	Monarch	Rather low % take of buds (1).	East Malling, England	2
232	,,	,,	,,	,,	Pershore Yellow Egg	Fair % take of buds (1).	,,	2, 73
233	,,	,,	,,	,,	Pond's Seedling	Rather low % take of buds (1).	,,	2
234	,,	,,	,,	,,	President	Very high % take of buds (1), trees all alive at 14 years.	,,	2, 73
235	,,	,,	,,	,,	Victoria	One 14-year-old tree broke off cleanly at union.	,,	79
236	,,	,,	,,	*P. insititia*	Bradley's King	Good % take of buds (1).	,,	2
237	,,	Common Mussel	,,	*P. cerasifera*	Myrobalan or Cherry Plum	Very low % take of buds (1).	,,	2
238	,,	,,	,,	*P. domestica*	Belle de Louvain	Good % take of buds (1).	,,	2
239	,,	,,	,,	,,	Czar	Fair to high % take of buds and grafts (3+) and mortality up to 13 years very slight.	,,	2, 73
240	,,	,,	,,	,,	Early Rivers (River's Early Prolific)	Very high % take of buds (1), trees all alive at 14 years.	,,	2, 73
241	,,	,,	,,	,,	Martin's Purple Egg	Fair % take of buds (1), trees all alive at 11 years.	,,	2
242	,,	,,	,,	,,	Monarch	Rather low % take of buds (1).	,,	2
243	,,	,,	,,	,,	Pond's Seedling	,, (1)	,,	2
244	,,	,,	,,	,,	President	Very high % take of buds (1), trees all alive at 14 years.	,,	2, 73
245	,,	,,	,,	,,	Utility	Very low % take of buds (1).	,,	2
246	,,	,,	,,	,,	Victoria	% take very variable for reasons other than incompatibility, trees all alive at 14 years.	,,	2

247	,,	,,	,,	*P. insititia*	Black Bullace	Very low % take of buds (1).	,,	2, 73
248	,,	,,	,,	,,	Bradley's King	Variable % take of buds (2).	,,	2
249	,,	St. Julien	seedling	*P. cerasifera*	Myrobalan or Cherry Plum	Rather low % take of buds (1).	,,	2, 73
250	,,	,,	,,	,,	,,	Growth uneven.	,,	74
251	,,	,,	,,	*P. domestica*	Varieties in general	The safest stock for Domestica plums in northern Canada.	Canada	121
252	,,	,,	,,	,,	Several varieties	Trees satisfactory at 10 years old.	N.Y. State, U.S.A.	84
253	,,	,,	,,	,,	Denniston's Superb Gage	Rather low % take of buds (1).	East Malling, England	2
254	,,	,,	,,	,,	Giant Prune	High % take of buds (1).	,,	2
255	,,	,,	,,	*P. insititia*	Black Bullace	No trees surviving more than 2 years.	,,	2
256	,,	,,	,,	,,	Drap d'Or	Trees satisfactory at 10 years old.	N.Y. State, U.S.A.	84
257	,,	,,	,,	,,	Prune Damson	No trees surviving more than 2 years.	East Malling, England	2
258	,,	,,	,,	,,	Shropshire	Trees satisfactory at 10 years old.	N.Y. State, U.S.A.	84
259	,,	St. Julien de Toulouse G	layered (clonal)	*P. domestica*	Belle de Louvain	Good % take of buds (1).	East Malling, England	2
260	,,	,,	,,	,,	Czar	Low % take of buds (3+), and heavy loss of both grafted and budded trees within 2 years.	,,	2
261	,,	,,	,,	,,	Giant Prune	Good % take of buds (1).	,,	2
262	,,	,,	,,	,,	Monarch	,, (1).	,,	2
263	,,	,,	,,	,,	Pond's Seedling	Rather low % take of buds (1).	,,	2
264	,,	,,	,,	,,	Victoria	% take of buds and grafts mostly high (3+), mortality of trees up to 2 years nil or very slight.	,,	2
265	*P. Mume*	Japanese apricot	seedling	*P. cerasifera*	Myrobalan or Cherry Plum	Union smooth and apparently strong.	California, U.S.A.	166
266	,,	,,	,,	*P. domestica*	Clyman	,,	,,	166
267	,,	,,	,,	,,	Grand Duke	Poor growth and delayed foliation.	,,	166

TABLE 2—*continued*

No.	Stock.			Scion.		Behaviour.	Where observed.	Cited from.
	Species.	Variety.	How propagated.	Species.	Variety.			
268	*P. Mume*	Japanese apricot	seedling	*P. domestica*	Imperial	Poor growth and delayed foliation.	California, U.S.A.	166
269	,,	,,	,,	,,	Sugar Prune	Trees at 4 years growing well, though most have slight bulge at union.	,,	166
270	,,	,,	,,	,,	Tragedy	Tendency to break at union third year.	,,	166
271	,,	,,	,,	*P. salicina* (?)	Beauty	Weak growth and evidence of incompatibility.	,,	166
272	,,	,,	,,	,,	Burbank	,,	,,	166
273	,,	,,	,,	,,	Santa Rosa	Tendency to break at union.	,,	166
274	,,	,,	,,	*P. salicina* × *P. Simonii*	Wickson	,,	,,	166
275	*P. Persica*	Peaches in general	—	*P. americana*	Stoddard	Did poorly.	Vermont, U.S.A.	170, 184, 185
276	,,	,,	—	*P. domestica*	Plums in general	Evidence of interference with conduction at unions which may result in death.	California, U.S.A.	135
277	,,	,,	various	,,	Some plums, most prunes	Some make satisfactory trees, others tend to break at the union, especially when nursery grafted on to seedlings.	,,	90
278	,,	,,	seedling	,,	Some prunes	Appear to lack affinity.	Victoria, Australia	42
279	,,	,,	—	,,	Most prunes	Make strong unions.	California, U.S.A.	89
280	,,	,,	seedling	,,	Angelina Burdett	Trees at 10 years larger than on Myrobalan.	N.S.W., Australia	32
281	,,	,,	,,	,,	Blue Imperatrice	,,	,,	32
282	,,	,,	—	,,	Burton (Prune)	One of very few prunes satisfactory on peach.	California, U.S.A.	90
283	,,	,,	top-worked	,,	California Blue (Vacaville)	Trees about 15 years from grafting, though enlargements at base of scion are held to indicate some incompatibility.	,,	108
284	,,	,	,,	,,	,,	Lacks affinity.	,,	91

285	,,	,,	seedling	,,	Columbia	Incompatible, specific effect not stated.	,,	191
286	,,	,,	,,	,,	Diamond	,,	,,	191
287	,,	,,	,,	,,	,,	Considerable breakage often occurs.	,,	90
288	,,	,,	,,	,,	,,	Forms one of the poorest unions among European plums, though some trees may live and crop satisfactorily for a number of years.	Pacific States, U.S.A.	107
289	,,	,,	—	,,	,,	Makes very poor union.	California, U.S.A.	96
290	,,	,,	—	,,	,,	Unsuitable.	U.S.A.	153
291	,,	,,	top-worked	,,	,,	Grafts surviving early years form good tops.	California, U.S.A.	90
292	,,	,,	,,	,,	French Prune (d'Agen)	One of very few prunes satisfactory on peach.	,,	90
293	,,	,,	seedling	,,	,,	Trees at 10 years larger than on Myrobalan.	N.S.W., Australia	32
294	,,	,,	top-worked	,,	Giant Prune	Satisfactory, although peach seedlings may give questionable results.	California, U.S.A.	90
295	,,	,,	,,	,,	Grand Duke	Some breakage may occur in early years, but successful orchards are also found.	,,	90
296	,,	,,	seedling	,,	,,	Trees at 10 years larger than on Myrobalan.	N.S.W., Australia	32
297	,,	,,	,,	,,	,,	Trees at 9 years normal-sized, healthy.	California, U.S.A.	45
298	,,	,,	,,	,,	,,	Incompatible, specific effect not stated.	,,	191
299	,,	,,	top-worked	,,	,,	Lacks affinity.	,,	91
300	,,	,,	seedling	,,	,,	Forms one of the poorest unions among European plums, though some trees may live and crop satisfactorily for a number of years.	Pacific States, U.S.A.	107
301	,,	,,	top-worked	,,	Hungarian	Satisfactory, although peach seedlings may give questionable results.	California, U.S.A.	90
302	,,	,,	,,	,,	Imperial	Lacks affinity.	,,	91
303	,,	,,	—	,,	Lombard	Said not to unite.	U.S.A.	85

TABLE 2—*continued*

No.	Stock.			Scion.		Behaviour.	Where observed.	Cited from.
	Species.	Variety.	How propagated.	Species.	Variety.			
304	*P. Persica*	Peaches in general	top-worked	*P. domestica*	President	Satisfactory, but poor results on Lovell peach.	California, U.S.A.	90
305	,,	,,	seedling	,,	,,	Trees at 10 years larger than on Myrobalan.	N.S.W., Australia	32
306	,,	,,	top-worked	,,	Quacken-boss	Satisfactory, although peach seedlings may give questionable results.	California, U.S.A.	90
307	,,	,,	—	,,	Red Date (Zucker Zwetsche)	Unsuitable.	U.S.A.	153
308	,,	,,	—	,,	Reine Claude (Green Gage)	Did poorly.	Vermont, U.S.A.	170, 184, 185
309	,,	,,	seedling	,,	Robe de Sergeant	Incompatible, specific effect not stated.	California, U.S.A.	191
310	,,	,,	,,	,,	,,	Does not show strong affinity.	,,	89, 90
311	,,	,,	,,	,,	,,	Does not bud well.	N.S.W., Australia	32
312	,,	,,	,,	,,	Standard Prune	Trees at 10 years larger than on Myrobalan.	,,	32
313	,,	,,	,,	,,	Sugar Prune	Incompatible, specific effect not stated.	California, U.S.A.	191
314	,,	,,	top-worked	,,	,,	Lacks affinity.	,,	91
315	,,	,,	—	,,	,,	Makes very poor union.	,,	96
316	,,	,,	seedling	,,	Tragedy (Prune)	Incompatible, specific effect not stated.	,,	191
317	,,	,,	top-worked	,,	,,	Satisfactory, although peach seedlings may give questionable results.	,,	90
318	,,	,,	seedling	,,	Washington	Incompatible, specific effect not stated.	,,	191
319	,,	,,	,,	,,	,,	Said not to unite.	U.S.A.	85
320	,,	,,	,,	,,	Yellow Egg	,,	,,	85
321	,,	,,	,,	,,	,,	Incompatible, specific effect not stated.	California, U.S.A.	191
322	,,	,,	,,	*P. insititia*	Damson	Said not to unite.	U.S.A.	85

323	,,	,,	,,	,,	Shropshire	Trees at 10 years old had grown well and fruited better than on other stocks.	N.Y. State, U.S.A.	84
324	,,	,,	—	*P. Munsoniana*	Newman	Did comparatively well.	Vermont, U.S.A.	170, 185
325	,,	,,	seedling	,,	Pottawattamie	A single tree grew and cropped fairly well up to 10 years old.	N.Y. State, U.S.A.	84
326	,,	,,	,,	,,	Wild Goose	,,	,,	84
327	,,	,,	–	*P. Munsoniana* × ?	Milton	Did poorly, trees dying within 2 years.	Vermont, U.S.A.	170, 184
328	,,	,,	–	*P. salicina* and hybrids	Japanese plums in general	Make excellent trees.	U.S.A.	19
329	,,	,,	top-worked	,,	Most varieties tested	Satisfactory.	California, U.S.A.	90
330	,,	,,	—	,,	Most common types	,,	Pacific States, U.S.A.	107
331	,,	,,	seedling	*P. salicina*	Abundance	Trees at 10 years old had grown and fruited satisfactorily.	N.Y. State, U.S.A.	84
332	,,	,,	,,	,,	Burbank	,,	,,	84
333	,,	,,	,,	,,	Chabot	,,	,,	84
334	,,	,,	—	,,	,,	Did poorly, trees dying within 2 years.	Vermont, U.S.A.	170, 184
335	,,	,,	top-worked	*P. salicina* × *P. Simonii*	Climax	Unsatisfactory.	California, U.S.A.	90, 91
336	,,	Elberta	,,	*P. domestica*	Grand Duke	Trees at 10 years rather stunted.	,,	45
337	,,	Lovell	,,	,,	President	Poor results.	,,	90
338	,,	Salwey	,,	,,	Grand Duke	Trees at 10 years rather stunted.	,,	45
339	*P. pumila*	Sand Cherry	seedling	*P. americana*	All varieties tested	Some trees dwarfed, but healthy and with perfect unions at 19 years.	Canada	121
340	,,	Sand Cherry, 3 selections	layered (clonal)	*P. domestica*	Denniston's Superb Gage	Very low % take of buds (1) and trees too weak to be of any value.	East Malling, England	2
341	*P. pumila* var. *Besseyi*	Western Sand Cherry	seedling	,,	Plums in general	Uncongenial, union not durable, trees short-lived.	S. Dakota, U.S.A.	70
342	,,	,,	,,	*P. salicina*	Japanese plums in general	Apparently satisfactory dwarfing stock.	,,	70

TABLE 2—*continued*

No.	Stock. Species.	Stock. Variety.	Stock. How propagated.	Scion. Species.	Scion. Variety.	Behaviour.	Where observed.	Cited from.
343	*P. salicina*	Japanese plums in general	—	*P. domestica*	Plums and prunes	Unsuitable.	U.S.A.	153
344	,, (?)	Apex	top-worked	,,	All varieties tested	Growth may start vigorously, but soon ceases.	California, U.S.A.	90
345	,, (?)	,,	,,	*P. salicina* and hybrids	Most varieties tested	Do well.	,,	90
346	,,	,,	,,	*P. salicina*	Kelsey	Results variable, some trees failing.	,,	90
347	,,	,,	,,	*P. salicina* × *P. americana*	Gaviota	,,	,,	90
348	,,	,,	,,	*P. salicina* × *P. Simonii*	Wickson	,,	,,	90
349	,, (?)	Beauty	,,	*P. domestica*	European plums in general	Growth may start vigorously, but soon ceases.	,,	90
350	,,	,,	,,	*P. salicina* and hybrids	Most varieties tested	Do well.	,,	90
351	,,	,,	,,	*P. salicina*	Burbank	Results variable.	,,	90
352	,,	,,	,,	,,	Kelsey	,,	,,	90
353	,,	,,	,,	*P. salicina* × *P. americana*	Gaviota	,,	,,	90
354	,,	,,	,,	*P. salicina* × *P. Simonii*	Wickson	,,	,,	90
355	,,	Burbank	,,	*P. domestica*	All varieties tested	Poor results.	,,	90
356	,,	,,	,,	*P. salicina* and hybrids	Most varieties tested	,,	,,	90
357	,,	,,	,,	*P. salicina* (?)	Apex	Satisfactory.	,,	90
358	,,	,,	,,	,, (?)	Beauty	,,	,,	90

359	,,		,,	,,	,, (?)	Duarte	,,	,,	90
360	,,		,,	,,	,,	Santa Rosa	,,	,,	90
361	,,		,,	,,	,,	Satsuma	,,	,,	90
362	,,		,,	,,	*P. salicina* × *P. Simonii*	Wickson	Questionable in a few cases, though mainly satisfactory.	,,	90
363	,,		,,	,,	*P. salicina* × ?	Formosa	,,	,,	90
364	,,	(?)	Duarte	,,	*P. domestica*	All varieties tested	Poor results.	,,	90
365	,,		,,	,,	*P. salicina* and hybrids	Many varieties	They make good unions, but lack vigour.	,,	90
366	,,		,,	,,	*P. salicina* (?)	Apex	Successful.	,,	90
367	,,		,,	,,	,, (?)	Beauty	,,	,,	90
368	,,		,,	,,	,,	Santa Rosa	,,	,,	90
369	,,		,,	,,	,,	Satsuma	,,	,,	90
370	,,		,,	,,	*P. salicina* × *P. Simonii*	Climax	,,	,,	90
371	,,		,,	,,	*P. salicina* × ?	Formosa	,,	,,	90
372	,,		Kelsey	,,	*P. domestica*	All varieties tested	Failures.	,,	90
373	,,		,,	,,	*P. salicina* and hybrids	Most varieties tested	Good results.	,,	90
374	,,		,,	,,	*P. salicina*	Burbank	Trees stunted, growth slow.	,,	90
375	,,		Santa Rosa	,,	*P. domestica*	All varieties tested	Poor growth and cropping.	,,	90
376	,,		,,	,,	*P. salicina* and hybrids	Most varieties tested	Good results.	,,	90
377	,,		,,	,,	*P. salicina*	Kelsey	Lacks vigour, but not a complete failure.	,,	90, 91
378	,,		Satsuma	,,	*P. domestica*	All varieties tested	Poor growth and cropping.	,,	90
379	,,		,,	,,	*P. salicina* and hybrids	Most varieties tested	Good results.	,,	90
380	,,		,,	,,	*P. salicina*	Kelsey	Lacks vigour, but not a complete failure.	,,	90

TABLE 2—*continued*

No.	Stock.			Scion.		Behaviour.	Where observed.	Cited from.
	Species.	Variety.	How propagated.	Species.	Variety.			
381	*P. salicina* · *P. americana*	Gaviota	top-worked	*P. domestica*	All varieties tested	None a success.	California, U.S.A.	90
382	,,	,,	,,	*P. salicina* and hybrids	Most varieties tested	Good results.	,,	90
383	,,	,,	,,	*P. salicina*	Kelsey	Questionable results.	,,	90
384	*P. salicina* × *P. Simonii*	Climax	,,	*P. domestica*	All varieties tested	Trees may live for some years, but are too weak to crop.	,,	90
385	,,	,,	,,	*P. salicina* and hybrids	Most varieties tested	Satisfactory.	,,	90
386	,,	,,	,,	*P. salicina*	Burbank	Makes doubtful union.	,,	90
387	,,	Wickson	,,	*P. domestica*	All varieties tested	Unsuccessful.	,,	90
388	,,	,,	,,	,,	Grand Duke	Trees stunted and chlorotic after 8 years.	,,	45
389	,,	,,	,,	*P. salicina* and hybrids	Most varieties tested	Satisfactory.	,,	90
390	,,	,,	,,	*P. salicina*	Kelsey	Unreliable.	,,	90
391	*P. salicina* × ?	Formosa	,,	*P. domestica*	Most varieties	Unite, but growth soon ceases, producing stunted, short-lived trees.	,,	90
392	,,	,,	,,	,,	Grand Duke	Trees showing some die-back in 3-4 years, stunted and rather chlorotic after 10 years.	,,	45
393	,,	,,	,,	,,	President	,,	,,	45
394	,,	,,	,,	*P. salicina* and hybrids	Most varieties tested	Appear to do well.	,,	90
395	,,	,,	,,	*P. salicina*	Santa Rosa	Results variable.	,,	90
396	,,	,,	,,	*P. salicina* × *P. Simonii*	Wickson	,,	,,	90

TABLE 3

ROOTSTOCKS TESTED FOR PEACHES, *PRUNUS PERSICA* AND *P. SIMONII**

No.	Stock.			Scion.		Behaviour.	Where observed.	Cited from.
	Species.	Variety.	How propagated.	Species.	Variety.			
1	*P. Amygdalus*	Almonds in general	—	*P. Persica*	Peaches in general	One of the recommended stocks.	France	9
2	,,	,,	seedling	,,	,,	Makes good union.	California, U.S.A.	132
3	,,	,,	top-worked	,,	All varieties tested	Seem to show affinity.	,,	91
4	,,	Sweet and bitter almonds	seedling	,,	Peaches in general	Makes a satisfactory union.	U.S.A.	22
5	,,	Hard-shelled and sweet almonds	,,	,,	,,	A hardy, strong stock.	California, U.S.A.	87
6	,,	Sweet almond	—	,,	,,	A suitable stock.	England	20
7	,,	Almonds in general	seedling	,,	Brigg's Red May	No definite signs of incompatibility up to 20 years.	South Australia	140
8	,,	,,	,,	,,	Elberta	,,	,,	140
9	,,	,,	,,	,,	Nicholl's Orange Cling	,,	,,	140
10	,,	,,	,,	,,	Salwey	,,	,,	140
11	*P. Armeniaca*	Apricots in general	—	,,	Peaches in general	Grafted with difficulty.	France	9
12	,,	,,	—	,,	,,	,,	U.S.A.	82
13	,,	,,	seedling	,,	,,	Not very compatible, and though some fair results, value commercially doubtful.	,,	22
14	,,	,,	—	,,	,,	Unsuitable.	,,	153
15	,,	,,	seedling	,,	,,	Union not always successful.	California, U.S.A.	69
16	,,	,,	,,	,,	,,	Union often unsuccessful.	,,	169
17	,,	,,	,,	,,	,,	Sometimes uncongenial, but no tendency to break at union.	,,	132

* *P. Simonii* belongs to section *Amygdalus* (almond and peach) of genus *Prunus*, and Bailey (5) groups it with peaches, although in habit of growth and in fruit it more closely resembles the plums.

TABLE 3—*continued*

No.	Stock.			Scion.		Behaviour.	Where observed.	Cited from.
	Species.	Variety.	How propagated.	Species.	Variety.			
18	*P. Armeniaca*	Apricots in general	top-worked	*P. Persica*	Peaches in general	Some breakage at union, affinity questionable.	California, U.S.A.	91
19	,,	,,	seedling	,,	Brigg's Red May	Trees very stunted and unfruitful.	South Australia	140
20	,,	,,	,,	,,	Elberta	Trees rather stunted and unfruitful.	,,	140
21	,,	,,	,,	,,	Nicholl's Orange Cling	,,	,,	140
22	,,	,,	,,	,,	Salwey	Trees very stunted and unfruitful.	,,	140
23	*P. cerasifera*	Myrobalan	—	,,	Peaches in general	Union frequently imperfect, trees dwarfed.	U.S.A.	7, 8
24	,,	,,	—	,,	,,	Unsuitable.	,,	153
25	,,	,,	—	,,	,,	Has proved unsatisfactory.	,,	87
26	,,	,,	top-worked	,,	,,	Do not take very well.	California, U.S.A.	90
27	,,	,,	seedling	,,	Many varieties	Union formed readily, but subsequent behaviour very variable, many trees dying towards end of first year.	,,	97
28	,,	,,	—	,,	Peaches in general	Trees too short-lived.	England	20
29	,,	,,	seedling	,,	Brigg's Red May	Trees very stunted and dying prematurely.	South Australia	50, 140
30	,,	,,	,,	,,	Elberta	Trees very stunted and unfruitful.	,,	50, 140
31	,,	,,	,,	,,	Nicholl's Orange Cling	,,	,,	50, 140
32	,,	,,	,,	*P. Simonii*	Simon or Apricot plums in general	Takes well.	N.Y. State, U.S.A.	5
33	,,	Myrobalan B	layered (clonal)	*P. Persica*	Hale's Early Peach	Fair % 1-year-old trees (2)*, but all dead in second year.	East Malling, England	2, 193
34	*P. cerasifera* × *P. Munsoniana*	Marianna	seedling and clonal	,,	Peaches in general	Dying back after a few years, unless own-rooted.	Tennessee, U.S.A.	118, 120

* The figure in brackets refers to the number of seasons in which the combination was tested.

35	,,	,,	seedling	,,	Many varieties	Union formed readily, but subsequent behaviour very variable, many trees dying towards end of first year.	California, U.S.A.	97
36	,,	,,	,,	*P. Simonii*	Simon or Apricot plums in general	Takes well.	N.Y. State, U.S.A.	5
37	*P. Davidiana*	Chinese Peach	,,	*P. Persica*	Peaches in general	Makes good union.	,,	194
38	,,	,,	,,	,,	,,	Considered promising.	California, U.S.A.	132
39	,,	,,	—	,,	,,	Does well.	,,	169
40	*P. domestica*	Plums in general	—	,,	,,	One of the recommended stocks. May include *P. insititia* types among "plums", but not stated.	France	9
41	,,	Cultivated types	—	,,	,,	Unsuitable.	U.S.A.	153
42	,,	,,	top-worked	,,	,,	Do not take very well.	,,	22
43	,,	,,	,,	,,	,,	Generally fail.	,,	90
44	,,	Varieties in general	,,	,,	,,	Usually fail to show compatibility.	,,	91
45	,,	Plums in general	seedling	*P. Simonii*	Simon or Apricot plums in general	Takes well.	N.Y. State, U.S.A.	5
46	,,	Brompton	layered (clonal)	*P. Persica*	Hale's Early Peach*	Good take and growth to 5 years.	East Malling, England	2, 193
47	,,	Brussels	,,	,,	,,	0-low % 1-year-old trees (2), all dead by end of second year.	,,	2
48	,,	Common Plum	,,	,,	,,	Very variable % 1-year-old trees (3), all dead by end of second year.	,,	2, 193
49	,,	Kroosjespruim	,,	,,	,,	Good take and growth to 5 years.	,,	2, 193
50	,,	Merunka	seedling	,,	Peaches in general	One of the best rootstocks.	Germany	158
51	,,	Pershore	layered (clonal)	,,	Hale's Early Peach	Good take and growth to 5 years.	East Malling, England	2, 193

* Peregrine has also made good trees on this stock.—Ed.

TABLE 3—*continued*

No.	Stock. Species.	Stock. Variety.	How propagated.	Scion. Species.	Scion. Variety.	Behaviour.	Where observed.	Cited from.
52	*P. insititia*	Black Damas A	layered (clonal)	*P. Persica*	Hale's Early Peach	0-100% 1-year-old trees (5), all dead by end of the season.	East Malling, England	2, 193
53	,,	Black Damas B	,,	,,	,,	Good take and growth to 5 years.	,,	193
54	,,	Black Damas C	,,	,,	,, *	,,	,,	2, 193
55	,,	Black Damas D	,,	,,	,,	Good take and growth to 5 years.	,,	2, 193
56	,,	Broad-leaved Shiny Mussel	,,	,,	,,	Some indication of delayed incompatibility in a tree dying in its fourth year.	,,	2, 193
57	,,	Common Mussel	,,	,,	,, *	Good take and growth to 5 years.	,,	2, 193
58	,,	Damson Plum	—	,,	Peaches in general	A suitable stock.	England	20
59	,,	Mussel (Muscle)	—	,,	,,	,,	,,	20
60	,,	Narrow-leaved Shiny Mussel	layered (clonal)	,,	Hale's Early Peach	Some indication of delayed incompatibility in a tree dying in its second year.	East Malling, England	2, 193
61	,,	St. Julien	—	,,	Peaches in general	Union frequently imperfect, trees dwarfed.	U.S.A.	7
62	,,	,,	seedling	,,	Alexander	Failed to unite.	Germany	158
63	,,	,,	,,	,,	Proskau	,,	,,	158
64	,,	,,	,,	,,	Triumph	Many grafts died after scions had made about 1 foot growth.	,,	158
65	,,	St. Julien A	layered (clonal)	,,	Hale's Early Peach	Good % 1-year-old trees.	East Malling, England	2
66	,,	St. Julien B	,,	,,	,,	5 out of 6 trees failed to survive first year after re-planting.	,,	2
67	,,	St. Julien C	,,	,,	,,	Good % 1-year-old trees.	,,	2
68	,,	St. Julien D	,,	,,	,,	0-high % 1-year-old trees (6), all dead by end of the season.	,,	2

* Peregrine has also made good trees on these stocks.—ED.

69	,,	St. Julien G (St. Julien de Toulouse)	,,	,,	,,	Dying back of scions in first few years.	,,	2, 193
70	,,	St. Julien K	,,	,,	,,	0-very low % 1-year-old trees (4), all dead by end of season.	,,	2
71	*P. maritima*	Beach plum	—	,,	Peaches in general	Buds made good growth till mid-season, then all died out within 2-3 weeks.	Iowa, U.S.A.	122
72	*P. Mume*	Japanese apricot	seedling	,,	5 varieties	Mostly unsatisfactory, some delayed foliation, trees much dwarfed. Some, e.g. Muir, showed abnormal rolled leaves lacking green colour as from the first season. All except Lovell showed marked overgrowth at union.	California, U.S.A.	166
73	,,	,,	,,	,,	Lovell	Trees slightly dwarfed, but all alive at 4 years in orchard. Suggested for trial as an interstock.	,,	166
74	*P. Persica*	Peaches in general	various	,,	Peaches in general	No cases of incompatibilities mentioned.	Various	Various
75	,,	,,	seedling	*P. Simonii*	Simon Apricot plums in general	Takes well.	N.Y. State, U.S.A.	5
76	*P. Persica* · *P. Amygdalus*	Peach × Almond Hybrid	,,	*P. Persica*	Brigg's Red May	No definite signs of incompatibility up to 20 years.	South Australia	140
77	,,	,,	,,	,,	Elberta	,,	,,	140
78	,,	,,	,,	,,	Nicholl's Orange Cling	,,	,,	140
79	,,	,,	,,	,,	Salwey	,,	,,	140
80	*P. pumila* var. *Besseyi*	Western Sand Cherry	,,	,,	Peaches in general	Apparently satisfactory as a dwarfing stock.	S. Dakota, U.S.A.	70
81	*P. salicina*	Varieties in general	top-worked	,,	,,	Usually fail to show compatibility.	California, U.S.A.	90, 91

TABLE 4

ROOTSTOCKS TESTED FOR APRICOTS, *PRUNUS ARMENIACA*

No.	Stock. Species.	Stock. Variety.	Stock. How propagated.	Scion. Variety.	Behaviour.	Where observed.	Cited from.
1	*P. americana*	—	—	Varieties in general	Union good, seems satisfactory.	Iowa, U.S.A.	19
2	*P. Amygdalus*	Almonds in general	seedling	,,	Used in S. France, affinity, however, not stated.	France	9
3	,,	,,	—	,,	Union very uncertain.	U.S.A.	22
4	,,	,,	—	,,	Union often imperfect, not recommended.	,,	7
5	,,	,,	seedling	,,	Poor unions, easily snapped by winds.	California, U.S.A.	191
6	,,	,,	trees top-worked	All varieties tested	Failures.	,,	91
7	*P. Armeniaca*	Apricots in general	various	Varieties in general	No mention of incompatibility by any authority.	Various	Various
8	*P. cerasifera*	Myrobalan	cuttings	,,	Listed as a suitable stock.	France	9
9	,,	,,	seedling	,,	Used in N.Y. State and California where of value despite a tendency for some trees to break at union.	U.S.A.	6, 69
10	,,	,,	—	,,	Union brittle, but orchards have been known to bear well.	California, U.S.A.	22
11	,,	,,	—	,,	Unions weak and lack vascular continuity.	Iowa, U.S.A.	19
12	,,	,,	seedling	,,	Often produces good crops, but tends to break during windy weather.	Victoria, Australia	42
13	*P. cerasifera* × *P. Munsoniana*	Marianna	—	,,	Makes a good stock.	U.S.A.	7
14	*P. domestica*	Varieties in general	trees top-worked	,,	Usually fail to show compatibility.	California, U.S.A.	91
15	,,	"Common plum"	seedling	,,	Some tendency in a few trees to break at unions.	N.Y. State, U.S.A.	6
16	,,	Brompton	vegetatively	,,	Trees die off after about 2 years.	England	20
17	,,	Brussels	,,	,,	,,	,,	20
18	,,	,,	—	,,	Stated to be used in England, affinity, however, not given.	,,	9

19	,, (?)	Grosspflaum	- -	,,	Stated to be used in Holland, affinity, however, not given.	Holland	9
20	*P. insititia*	Black Damson	seedling	,,	Listed as a suitable stock.	France	9
21	,,	Mussel (Muscle)	—	,,	Commonly used (in 1877).	England	20
22	,,	St. Julien	seedling	,,	Listed as a suitable stock.	France	9
23	,,	,,	—	,,	Unions weak and lack vascular continuity.	Iowa, U.S.A.	19
24	*P. Mume*	Japanese Apricot	seedling	5 varieties	Trees at 4 years very vigorous, union appears perfect.	California, U.S.A.	166
25	*P. Persica*	Peaches in general	-	Varieties in general	Does well.	U.S.A.	7
26	,,	,,	seedling	,,	The stock of possibly nine-tenths of the apricot trees.	California, U.S.A.; and South Africa	166 43
27	,,	,,	,,	,,	One of the two chief stocks.	California, U.S.A.	191
28	,,	,,	trees top-worked	,,	Show close affinity.	,,	91
29	,,	,,	seedling	,,	Probably the commonest stock, and is of value despite a tendency for some trees to break at union.	N.Y. State, U.S.A.	6
30	,	,,	—	,,	Grafted only with difficulty.	U.S.A.	82
31	,,	,,	seedling	,,	Commonly fail to make good unions.	,,	194
32	,,	,,	,,	,,	Do not often make good unions.	California, U.S.A.	169
33	*P. Pumila* var. *Besseyi*	Western Sand Cherry	,,	,,	Apparently satisfactory as a dwarfing stock.	S. Dakota, U.S.A.	70
34	*P. salicina*	Varieties in general	trees top-worked	,,	Usually fail to show compatibility.	California, U.S.A.	91

TABLE 5

ROOTSTOCKS TESTED FOR ALMONDS, *PRUNUS AMYGDALUS*

No.	Stock. Species.	Stock. Variety.	Stock. How propagated.	Scion. Variety.	Behaviour.	Where observed.	Cited from.
1	*P. Amygdalus*	Almonds in general	variously	Varieties in general	No mention is made of any incompatibilities between commercial varieties and any of the almond types used as stocks.	Various	Various
2	*P. Armeniaca*	Apricots in general	—	,,	Should be avoided.	California, U.S.A.	191
3	,,	,,	top-worked	,,	Shows little affinity.	,,	91
4	,,	,,	seedling	,,	Have to be double-worked.	Victoria, Australia	42
5	*P. cerasifera*	Myrobalan	,,	,,	The union is not very satisfactory.	California, U.S.A.	69, 169
6	,,	,,	—	,,	Trees short-lived.	U.S.A.	22
7	,,	,,	—	,,	Trees dwarfed, but union usually good.	,,	7
8	,,	,,	—	,,	,,	Victoria, Australia	42
9	*P. Davidiana*	Wild Chinese peach	seedling	,,	Unite well, longevity still to be tested.	U.S.A.	7
10	*P. domestica*	Varieties in general	trees top-worked	,,	Usually fail to show compatibility.	California, U.S.A.	90, 91
11	,, (?)	"Plums"	—	,,	Disappointing.	,,	191
12	,, (?)	,,	—	,,	Listed as a stock for almonds.	France	9
13	,,	Varieties in general	seedling	,,	Usually unsatisfactory.	Victoria, Australia	42
14	*P. Mume*	Japanese apricot	—	5 varieties	Stunted growth and/or very high mortality up to 4 years.	California, U.S.A.	166
15	*P. Persica*	Peaches in general	seedling	Varieties in general	Used extensively, no mention made of incompatibilities.	,,	69, 169
16	,,	,,	,,	,,	Forms perfect union.	South Africa	43
17	,,	,,	trees top-worked	,,	Show close affinity.	California, U.S.A.	91
18	,,	,,	—	,,	Make large satisfactory trees.	Victoria, Australia	42
19	*P. salicina*	Japanese plums in general	trees top-worked	,,	Usually fail to show compatibility.	California, U.S.A.	90, 91

TABLE 6

ROOTSTOCKS TESTED FOR CHERRIES, *PRUNUS AVIUM* AND *P. CERASUS*, ETC.

No.	Stock.			Scion.		Behaviour.	Where observed.	Cited from.
	Species.	Variety.	How propagated.	Species.	Variety.			
1	*P. americana*	—	—	*P. pumila* var. *Besseyi*	Western Sand cherry	Appears to be congenial.	S. Dakota, U.S.A.	70
2	*P. Avium*	Mazzard or Sweet cherry	various	*P. Avium* and *P. Cerasus*	Cherries in general	No mention made of any incompatible combination.	Various	Various
3	,,	,,	seedling	*P. Mahaleb*	Mahaleb (St. Lucie cherry)	Appears to be congenial.	Vermont, U.S.A.	35
4	,,	Cultivated varieties	—	,,	,,	Will not grow.	U.S.A.	82
5	,,	,,	—	,,	,,	Will not succeed as a graft.	France	155
6	*P. Cerasus*	Sour cherry	seedling	*P. Avium*	5 varieties	Trees dwarfed, showing overgrowth at union, but healthy at 24 years.	South Australia	50, 138
7	,,	Sour cherry selections	layered (clonal)	*P. Cerasus*	Morello	Dwarf trees but no mention of incompatibility.	East Malling, England	64
8	,,	Sour cherry cultivated varieties	—	*P. Mahaleb*	Mahaleb (St. Lucie cherry)	Will not grow.	U.S.A.	82
9	,,	,,	—	,,	,,	Will not succeed as a graft.	France	155
10	,,	Stockton Morello	vegetatively	*P. Avium*	Some varieties	Do not make good unions.	California, U.S.A.	69
11	,,	,,	suckers	,,	Varieties in general	All but one thought to be compatible; union strong despite some overgrowth.	,,	134
12	,,	,,	,,	,,	Chapman	Incompatible, has to be double worked.	,,	134
13	,,	,,	,,	*P. Cerasus*	Varieties in general	Compatible.	,,	134
14	,,	,,	,,	,,	All varieties tested	Union seems satisfactory.	Illinois, U.S.A.	13

TABLE 6 *continued*

No.	Stock.			Scion.		Behaviour.	Where observed.	Cited from.
	Species.	Variety.	How propagated.	Species.	Variety.			
15	*P. demissa*	Western Choke cherry	—	*P. Avium*	Varieties in general	Unsuitable.	U.S.A.	153
16	,,	,,	—	*P. Cerasus*	,,	,,	,,	153
17	*P. Mahaleb*	Mahaleb (St. Lucie cherry)	seedling	Not stated	Cherries in general	Unites readily, recommended as a stock.	France	9
18	,,	,,	,,	,,	A few trees	Exceptions to general rule, trees being 50 years old and showing no dwarfing.	California, U.S.A.	134
19	,,	,,	,,	*P. Avium*	Many varieties	Good union, strong nursery tree, but shorter-lived than on Mazzard, trees dying from 15 to 20 years old.	N.Y. State, U.S.A.	176
20	,,	,,	,,	,,	Varieties in general	Dwarfing in effect and relatively short-lived.	U.S.A.	7, 86, 134
21	,,	,,	—	,,	,,	Trees short-lived, not recommended.	Victoria, Australia	42
22	,,	,,	seedling	,,	17 varieties	Over 50% of the trees died within 14 years and many remaining were weak and moribund.	N.Y. State, U.S.A.	98, 99, 100
23	,,	,,	,,	,,	5 varieties	Early growth vigorous, but declined prematurely and some trees died.	South Australia	50, 138
24	,,	,,	,,	,,	Coe (Coe's Transparent)	Trees started dying when 8-10 years old.	Tennessee, U.S.A.	119
25	,,	,,	,,	*P. Avium* and *P. Cerasus*	Varieties in general	The most widely used stock in the U.S.A. and in South Africa.	U.S.A.; and South Africa	7, 194 43
26	,,	,,	,,	*P. Avium* × *P. Cerasus*	9 "Duke" varieties	Over 50% of the trees died within 14 years.	N.Y. State, U.S.A.	98, 99, 100
27	,,	,,	,,	*P. Cerasus*	Many varieties	Good union, strong nursery tree, good orchard tree to 16-22 years when trees begin to die out.	,,	176
28	,,	,,	,,	,,	Varieties in general	Dwarfing in effect and relatively short-lived.	U.S.A.	7, 86, 134
29	,,	,,	—	,,	,,	Trees short-lived, not recommended.	Victoria, Australia	42

30	,,	,,		,,	,,	Likely to be very unsatisfactory.	U.S.A.	8
31	,,	,,	seedling	,,	14 varieties	Over 50% of the trees died within 14 years, and many remaining were weak and moribund.	N.Y. State, U.S.A.	98, 99, 100
32	,,	,,	,,	,,	Brusseler Braune	Unhealthy growth and some mortality at 2-3 years.	Iowa, U.S.A.	19
33	,,	,,	,,	,,	Cerise de Ostheim	,,	,,	19
34	,,	,,	,,	,,	Double Natte	,,	,,	19
35	,,	,,	,,	,,	Early Richmond	Trees started dying when 8-10 years old.	Tennessee, U.S.A.	119
36	,,	,,	,,	,,	Montmorency	,,	,,	119
37	,,	Mahaleb (certain selections)	layered (clonal)	,,	Morello	Growth rate declining after 5-6 years.	East Malling, England	64
38	,,	,,	,,	,,	,,	Trees lost early vigour by 9-10 years, and some had died. May indicate some incompatibility.	,,	2
39	,,	,,	seedling	,,	,,	Unhealthy growth and some mortality at 2-3 years.	Iowa, U.S.A.	19
40	,,	,,	,,	,,	Shadow Amarelle	,,	,,	19
41	,,	,,	,,	,,	Späte Amarelle	,,	,,	19
42	*P. maritima*	Beach plum	—	,,	Montmorency	Trees dwarfed but seem to do very well.	,,	122
43	*P. Padus*	Bird cherry	seedling	*P. Avium*	Seneca	Buds unite, but break from the stock the second season.	N.Y. State, U.S.A.	176
44	,,	,,	,,	,,	Windsor	,,	,,	176
45	,,	,,	,,	,,	Yellow Spanish	,,	,,	176
46	,,	,,	,,	*P. Cerasus*	Montmorency	,,	,,	176
47	,,	,, (selection)	layered (clonal)	,,	Morello	Completely incompatible.	East Malling, England	2
48	,,	Bird cherry	—	*P. Laurocerasus*	Cherry Laurel	Does well.	Massachusetts, U.S.A.	44
49	*P. pennsylvanica*	Wild Red cherry	seedling	Not stated	Some trees	Has given good results.	Ottawa, Canada	3
50	,,	,,	,,	*P. Avium*	Varieties in general	Unite readily, ultimate effect not, however, tested.	U.S.A.	7

TABLE 6 *continued*

No.	Stock.			Scion.		Behaviour.	Where observed.	Cited from.
	Species.	Variety.	How propagated.	Species.	Variety.			
51	*P. pennsylvanica*	Wild Red cherry	—	*P. Avium*	Varieties in general	Unites perfectly.	Iowa, U.S.A.	19
52	,,	,,	seedling	,,	Mazzard	Appears to be compatible.	Vermont, U.S.A.	35
53	,,	,,	,,	,,	Windsor	No sign of incompatibility.	,,	35
54	,,	,,	—	*P. Avium* × *P. Cerasus*	All "Duke" cherries tested	United perfectly.	Iowa, U.S.A.	19
55	,,	,,	—	*P. Cerasus*	Varieties in general	,,	,,	19
56	,,	,,	seedling	,,	,,	Unite readily, ultimate effect not, however, tested.	U.S.A.	7
57	*P. Persica*	Peaches in general	,,	*P. Avium* and *P. Cerasus*	Cherries in general	Buds may unite, but always fail to make a tree.	South Africa	43
58	*P. Pseudo-cerasus*	Dai-Sakura	vegetatively	Not stated	European cherries	Used as a dwarfing stock, no mention of incompatibility.	Japan	86
59	*P. pumila*	Sand cherry	seedling	,,	Cherries in general	Shows promise as a dwarfing stock.	U.S.A.	7
60	,,	,,	,,	*P. Cerasus*	Varieties in general	Unites well.	Iowa, U.S.A.	19
61	*P. pumila* var. *Besseyi*	Western Sand cherry	,,	Not stated	Cherries in general	Shows promise as a dwarfing stock.	U.S.A.	7
62	,,	,,	,,	*P. Avium and P. Cerasus*	,,	Unite only with difficulty.	S. Dakota, U.S.A.	70
63	*P. serotina*	Rum or Wild Black cherry	—	*P. Avium*	Varieties in general	Unsuitable.	U.S.A.	153
64	,,	,,	seedling	,,	Seneca	Buds unite, but fail the second year.	N.Y. State, U.S.A.	176
65	,,	,,	,,	,,	Windsor	,,	,,	176
66	,,	,,	,,	,,	,,	Made poor union.	Vermont, U.S.A.	35
67	,,	,,	,,	,,	Yellow Spanish	Buds unite, but fail the second year.	N.Y. State, U.S.A.	176

68	,,	,,	-	*P. Cerasus*	Varieties in general	Unsuitable.	U.S.A.	153
69	,,	,,	seedling	,,	Early Richmond	Made poor union.	Vermont, U.S.A.	35
70	,,	,,	,,	,,	Montmorency	Buds unite, a few one- or two-year old trees develop ; but most fail.	N.Y. State, U.S.A.	176
71	*P. serrulata*	—	,,	*P. Avium*	Windsor	No sign of incompatibility to 6 years.	Vermont, U.S.A.	35
72	,,	—	,,	*P. Cerasus*	Early Richmond	,,	,,	35
73	*P. tomentosa*	-	,,	*P. Avium*	Seneca	Incompatible, buds fail to unite.	N.Y. State, U.S.A.	176
74	,,		,,	,,	Windsor	,,	,,	176
75	,,	-	,,	,,	Yellow Spanish	,,	,,	176
76	,,	—	,,	*P. Cerasus*	Montmorency	Incompatible, buds may appear to unite, but none develop shoots.	,,	176, 177
77	,,	3 selections	layered (clonal)	,,	Morello	Failed to make any growth.	East Malling, England	2
78	*P. virginiana*	Choke cherry	seedling	Not stated	Cherries in general	Makes very good union.	Oregon, U.S.A.	116
79	,,	,,	,,	*P. Avium*	Windsor	Made poor unions.	Vermont, U.S.A.	35
80	,,	,,	,,	*P. Cerasus*	Early Richmond	,,	,,	35

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